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JOURNAL OF PALEONTOLOGY

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E. C. CASE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICH.

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EDITORS

C. WYTHE COOKE, for The Paleontological Society.

J. MARVIN WELLER, for The Society of Economic Paleontologists and Mineralogists.

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THE BRACHIOPOD ZONAL INDICES OF THE STAGES COSTONIAN TO ONNIAN IN BRITAIN

B. B. BANCROFT[1]

ABSTRACT—The stages Costonian to Onnian correspond roughly to the lower half of the Upper Ordovician as conceived in England. They embrace seven stages, the Costonian, Harnagian, Soudleyan, Longvillian, Marshbrookian, Actonian, and Onnian. These stages are subdivided into 32 zones. The zonal indices are chosen from the Dalmanellacea, Orthacea, and Strophomenacea. The brachiopod indices include 14 new species and varieties, of which four are referred to *Onniella*, five to *Howellites* (new subgenus in *Resserella*), two to *Raymondella* (new genus), two to *Wattsella*, and one to *Dinorthis*. Two new brachiopod genera, *Soudleyella* and *Cryptothyris*, are also described. The indices referred to *Howellites*, *Raymondella*, and *Onniella* lie upon well-established trend lines, their respective positions in the trend being defined by the statistical characters of the ribbing. The same method of definition is used in describing the other indices referred to Dalmanellacea.

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INTRODUCTION

THE STAGES Costonian to Onnian were defined with reference to the Upper Ordovician rocks of East Shropshire. They embrace the entire thickness of that succession and correspond in a rough way with the lower half of the Upper Ordovician as conceived in England. More precisely, they are defined by the *Nemagraptus gracilis* horizon, in which is included the whole or part of the Costonian, and the *Onnia* horizon, which constitutes the Onnian. Still more precisely, they are defined with reference to their limiting zones. The relation of these stages to the other Upper Ordovician horizons is as follows:

Upper Ordovician

Hirnantian: With the *Hirnantia hirnantensis* fauna. The beds above the *Tretaspis seticornis* horizon. Typified by the Hirnant beds.

Ashgillian: With *Tretaspis seticornis*,

[1] John Bemis Beeston Bancroft was killed in action June 24, 1944, while serving with the Allied fleet during the liberation of France. Publication has been made possible by a memorial grant to The Paleontological Society by his mother, Mrs. M. A. H. Bancroft, of Nibley House, Blakeney, Gloucester, England.

but not precisely defined faunally. Type deposit, the *Staurocephalus* limestone.

Pusgillian: With the *Tretaspis kjaeri* group. Type deposit, the Dufton shales of Pusgill above the *Onnia* horizon.

Onnian Costonian: Including the *Pleurograptus linearis* horizon and part or all of the *Dicellograptus complanatus* horizon above; including part of the *Nemagraptus gracilis* horizon below.

DELIMITATION OF THE STAGES COSTONIAN TO ONNIAN

Costonian.—This is the stage of the post-Llandeilian type of *Marrolithus*, the base of the stage corresponding to the appearance of that type, and the summit to the displacement of *Marrolithus* by its derivative, *Reuscholithus*. It is also the stage of *Harknessella*, which is abundant at the lower horizons, and appears again at the summit. Apart from these fossils and a few short-ranging forms used as indices, the stage is rather poorly defined by positive criteria, most of the groups of species and subgenera with extensive ranges in the Costonian having extensive ranges in the Harnagian also. Thus *Smeathenella*, *Cliftonia andersoni* and the early type of the group of *Rafinesquina expansa* with peripheral shell thickening are equally characteristic of the Costonian and Harnagian, and serve to distinguish them from the succeeding stages. The Costonian is typified by the grits of Horderley, Hoar Edge and Coston in the East Shropshire area.

Harnagian.—The base of the Harnagian is defined by the appearance of *Reuscholithus* and *Salterolithus*, and the summit by the appearance in force of *Bröggerolithus*. Of the long-ranging forms *Reuscholithus* and *Ulricholithus* are alone known to be peculiar. The stage, however, is pre-eminently the stage of *Salterolithus*, that genus having a wide distribution in both the sandy and muddy facies during this period, whereas during the succeeding Soudleyan it is restricted almost exclusively to sandy deposits.

On account of the prevalence of the argillaceous facies little is known of the brachiopod faunas of the higher zones; but the sandy basal deposits yield faunas of strong Costonian affinities, and are interesting on account of the presence of an element that reappears in the Drummuck group (*Schizophorella* and a group of *Calymene*). The species and groups of species and many of the genera are quite distinct from the British Soudleyan fauna. The distinctive forms include: *Nieszkowskia*, *Acidaspis*, *Wattsella*, *Nicolella*, *Dolerorthis*, *Glyptorthis*, *Schizophorella*, *Anastrophia*, Phylloporinidae.

The type section is in the Harnage shales of Cound Brook, Cressage, Shropshire.

Soudleyan.—The characteristic fossils of this stage are *Rafinesquina expansa* and its allies (without peripheral shell thickening) and the early type of *Bröggerolithus:* both appear in abundance at the base, and both extend throughout the division. The upper limit is nearly precisely defined by the disappearance of *Rafinesquina expansa*, which extends only a few feet into the lower Longvillian, whilst *Bröggerolithus* has a more extensive range. Deposits of this age may also be distinguished from Harnagian and lower Longvillian beds by the presence of *Reuschella*, which appears in the lower part of the stage, and extends nearly to the summit.

In the British region the Soudleyan faunas are characterized by few elements, and are temporally segregated into provinces of which the main North Welsh area is the most important. In that area the fauna is specially characterized by the dalmanelloid *Resserella* (*Howellites*). The other provinces are relatively unimportant, and do not exhibit a continuous brachiopod facies. They embrace the Welshpool province, an arm of the argillaceous sea bed to the south with persistent *Salterolithus*, the graptolitic zone of Chirbury, and the East Shropshire area with *Soudleyella* and a special group of *Bröggerolithus*. The basal horizon and the upper division of the stage are characterized by certain faunal elements which extend throughout the Wales-Shropshire region.

The fossils of the zone of *Dinorthis multiplicata* at the summit of the Soudleyan are for the most part lower Longvillian species, and it was only the abundance of *Rafinesquina expansa*, and the absence of *Kjaerina* that led me to include it in the Soudleyan.

The typical section is in the Onny Valley beginning in the Glenburrell beds and ter-

minating at the summit of the middle Horderley sandstone.

Longvillian.—This stage is characterized by an abundance of the rafinesquinoid *Kjaerina*. That genus, already represented by a small and rare species in the upper beds of the Soudleyan, displaces *Rafinesquina* at the summit, the two genera occurring together in a few feet of strata referred to the Longvillian. The Longvillian is an extensive stage and includes a rapid succession of faunal divisions which, whilst sharply demarcated, contain many genetically related species. At certain horizons there existed more or less distinct faunal subregions in the British region. There are two substages:

1, The lower Longvillian: The *Kjaerina* of this division is plano-convex and without wrinkles, or with these only feebly developed. In Britain the stage is further characterized by the persistence of *Bröggerolithus* with elevated plates in E1, by the appearance of *Tentaculites, Resserella,* s. s., and the complete absence of Harknessellinae. From the point of view of interregional correlation it is noteworthy that *Chasmops conicophthalma* has its maximum in this stage, and disappears early in the succeeding substage. The longicaudate *Chasmops* appear near the summit of the lower Longvillian. The substage is typified by the upper Horderley sandstone.

2, The upper Longvillian: The first upper Longvillian *Kjaerina* includes large shells of lower Longvillian type. These are followed by plano-convex forms with short, strong wrinkles near the hinge, and these by forms with geniculate ventral valves. The stage is further characterized by the appearance at the base of *Longvillia* and new types of *Bröggerolithus,* and by the reappearance of Harknessellinae (*Reuschella*). A marked feature of the fauna is the relatively larger size of the genera which survived from the lower Longvillian, such as *Kjaerina* (*bipartita*), *Acaste* and *Raymondella*. This fact is correlated with a more or less marked hiatus at the base. *Chasmops macroura* occurs as a fairly common fossil about the middle of the substage. The type section is in the Longville flags of Longville Lane, from the base of the Alternata limestone to the 'Earthwork.'

Marshbrookian.—The most characteristic fossil is *Kjerulfina*, which ranges throughout the stage and disappears abruptly at the summit; it appears, however, as a rare fossil in the highest horizon of the Longvillian. The lower zones are specially characterized by coarsely ribbed *Wattsella*, which again constitutes a link with the Longvillian. The highest zone, on the other hand, with its abundant *Onniella* and *Hedstroemina* forms a transition horizon between this stage and the Actonian. Among other fossils *Tentaculites*, with closely set rings, *Longvillia* and *Chasmops macroura* are particularly abundant throughout, whilst *Tentaculites* cf. *T. obliquus* and a small *Triplecia* appear in the highest zone. The type section is through the highest beds of the Longville flags as exhibited in the lane through Marsh Wood, half a mile south of Marshbrook Station, East Shropshire.

Actonian.—The base of this stage is marked by the disappearance of *Kjerulfina* and *Tentaculites anglicus*, and the appearance of a large species of *Onniella* and *Colpomya. Bröggerolithus, Modiolopsis, Longvillia* and *Hedstroemina* disappear at a somewhat higher horizon, and about the same time appears the following characteristic Actonian fauna: *Remopleurides, Platylichas laxatus, Ampyx* cf. *A. rostratus, Oxydiscus acutus, "Nucula" varicosa. Onniella, Reuschella bilobata, Nicolella actoniae* and *Chasmops macroura* are found throughout this stage, and in the highest zone *Sowerbyella cylindrica* is a common fossil.

In Wales and Westmorland the Actonian includes the earliest deposits with *Tretaspis kjaeri, Phillipsinella* and other typical upper Bala fossils.

Type section: The Acton Scott beds below the *Onnia* horizon in the Onny River section east of Burrell's Coppice.

Onnian.—In Britain the base of this stage is defined by the appearance, and the summit by the disappearance, of the genus *Onnia*. The other fossils belong mainly to Actonian genera, but *Platylichas, Chasmops* and most of the lamellibranchs and larger brachiopods are of infrequent occurrence. *Remopleurides* and *Ampyx*, however, are somewhat more abundant than in the Actonian, and among new appearances may be noted the genus *Triarthrus*. The characteristic brachiopods are species of *Onniella,*

Chonetoidea and *Sowerbyella cylindrica*. The close of the Onnian is marked by the reappearance of *Tetraspis kjaeri*. Type section: In the Onny River section.

STRATIGRAPHY OF THE STAGES COSTONIAN TO ONNIAN IN THE BRITISH REGION

Costonian.—The close of the Llandeilian was marked by a general transgression. In the Wales-Shropshire region the sea extended into East Shropshire, where the grey grits of Hoar Edge and Coston were deposited upon rocks of Cambrian or Pre-Cambrian age. Locally, as in the Horderley district, these littoral sediments commence with an initial deposit; whilst elsewhere, as in the Cressage district, they are characterized by rapid lateral changes and hiatuses. Between Horderley and Cressage the Costonian thins out about the massif of the Church Stretton Hills, the peripheral grits of that district being of later age. The Church Stretton massif, like the Longmynd to the west, formed an island in the Costonian sea, and was only temporally submerged during the succeeding stages. Grits comparable to those of Coston appear on the west border of the Longmynd massif (the Spy Wood grit), but farther west they pass into the great mudstone series, and are indistinguishable lithologically from the Harnagian deposits. Only in the northwest of Wales do we again find a Costonian grit facies in the Welsh Sea.

Neither the Costonian nor Harnagian have been recognized in the Lake District or Westmorland, but in southwest Scotland the Stinchar limestone series presents a littoral grit facies comparable to that of East Shropshire, and, as in that area, it rests upon rocks of pre-Llandeilian age.

Harnagian.—At the end of the Costonian the Argillaceous facies extended eastwards into West Shropshire and East Shropshire, where they are represented by the Hagley shales and Harnage shales respectively. In East Shropshire the sequence often begins with a greenish grit, which is followed by sandy shales of the same colour. Around the Stretton Hills the lower beds consisting of coarse greenish grits exhibit a littoral facies. Above these basal deposits the great mass of the beds is of a finer character: they consist mainly of greenish-grey, orange-staining mudstones with sphæroidal weathering, and yield Cryptolithinae and graptolites. The same facies occurs at Welshpool, but in the intervening zone of Chirbury (on the west side of the Longmynd) the sediments are more purely argillaceous and yield few fossils except graptolites. To the southwest and west of Welshpool the sediments continue to increase in thickness, and are almost devoid of shelly fossils.

In the Girvan district of Scotland the Balclatchie mudstones are evidently of Harnagian age, but the typical fauna has not been found. A highly condensed argillaceous and graptolitic facies of the Harnagian occurs in the Moffat district.

Soudleyan.—In East Shropshire, Chirbury, and Welshpool areas the lower part of the Soudleyan consists of rapidly alternating flags and mudstones with elongate concretions (Pwll-y-Glo beds, Hagley shales, Glenburrell beds)[1] yielding dalmanelloids and *Bröggerolithus*. The same facies is found at Meifod, and extends westwards to the Bala District (Glyn Gower sandstone). Elsewhere in North Wales, as at Glyn Ceiriog and in Caernarvonshire, the sandstones are coarser and assume a more massive character.

The upper part of the Soudleyan of Horderley consists mainly of massive sandstones with shale partings, the higher and major part of the series constituting the Green and Purple sandstone. Passing over the zone of Chirbury we find a comparable series at Welshpool, where the greenish sandy mudstones below, and the purple mudstones and sandstones above, may be regarded as the deeper water, and more argillaceous equivalents of the sandstones of East Shropshire. To the west of Welshpool these deposits and the higher beds of the Pwll-y-Glo pass abruptly into a series of thick-bedded shelly mudstones, which constitute the prevailing types of sediments

[1] The lower part of these beds as well as the similar deposits at Meifod and Bala are referred to the Harnagian, the base of the Soudleyan being determined by the appearance of *Bröggerolithus* in great abundance. The classification is by no means satisfactory or convenient in this respect, and it is desirable that the correlates of the Glyn Gower sandstone should be placed in a separate stage. However, until the fossils of these deposits have been studied in greater detail it seems unwise to modify the classification.

throughout North Wales. But to the south of Bala the entire Soudleyan passes rapidly into unfossiliferous shales and merges with the great Harnagian mudstone series of the central Welsh depression. Of this theatre of persistent argillaceous sedimentation the zone of Chirbury forms a northwestern arm; here, too, the mudstone facies prevails throughout the Upper Ordovician. Passing southwards from the central Welsh depression the Soudleyan together with the Harnagian and Longvillian passes into a thin series of dark-grey and black graptolitic shales (*Dicranograptus* shales). The presence of the Soudleyan in the Lake district and Westmorland has not been established; in Scotland, on the other hand, a great part of the Ardmillan flags must be of this age.

Lower Longvillian.—In East Shropshire the lower Longvillian is most fully developed near Horderley, where it consists of massive grey and greenish sandstones (upper Horderley sandstone). North of Horderley the beds thin out towards the Stretton Hills, on the north side of which it presents a littoral facies. This facies is well seen at Chatwall, where it is reduced to a thin series of conglomerates and dirty muddy flags.

Massive sandstones similar to those at Horderley occur in the lower part of the substage at Meifod and Glyn Ceiriog (N. Berwyns) and in the middle part at Welshpool. In all these areas the highest beds consist of shelly mudstones or argillaceous sandstones, which at Welshpool and Meifod are markedly calcareous. When traced westwards the sandstones are replaced by mudstones, and calcareous ashes and ashy mudstones are developed throughout the series (Gelli Grin series of Bala). This is the typical North Welsh type of lower Longvillian.

Beds of this age have been found near Melmerby in Westmorland, where they consist of sandy and calcareous mudstones with typical shelly faunas, and the ashes underlying the upper Longvillian of Dufton belong to the same division. In the Girvan district the substage is evidently represented by part of the Ardmillan flags.

The lower Longvillian is a phase of highly condensed sedimentation and is characterized by rapid lateral changes in thickness and sediment, and by local hiatuses. Thus the lower zones thin out entirely within a distance of a mile in the Bala area, and the whole substage is absent on the south flank of the Church Stretton massif.[1]

Upper Longvillian.—South of the Church Stretton Hills the upper Longvillian commences with a series of bastard limestones, flags and sandy mudstones (Alternata limestone), which at Horderley rest with apparent conformity upon the highest beds of the lower Longvillian. At Soudley, on the other hand, the lower Longvillian is absent, and the Alternata limestone with a few inches of initial deposit at the base rests upon the Soudleyan sandstones. On the north side of the Church Stretton Hills the limestone itself changes character, passing into a coarse yellow sandstone with pebble beds.

Passing westwards into Wales the base of the substage at Bala is a bed of crystalline limestone 2 ft. thick, and comparable calcareous deposits are found at this horizon in other Welsh areas and in Westmorland. These basal limestones are evidently constituted by the washed-out shelly matter from contemporaneous and lower Longvillian deposits during a prolonged period of erosion and sorting; they are evidence of a widespread and prolonged hiatus at the base of the substage.

In East Shropshire the basal beds are followed by laminated, micaceous flagstones with subordinate mudstones (middle Longville flags). Deposits of the same age, but forming a much more attenuated series, occur in Westmorland, where they consist of shelly, calcareous mudstones with a few beds of black shale. These shales are identical with the typical Nod Glas facies, which has an important development in Wales, the north of England and south Scotland during this and the succeeding stages. At Gelli Grin in the Bala district the crystalline limestone is followed by a thin series of impure limestones and ashy mudstones, but about a mile to the west these beds thin out entirely, and the crystalline limestone is followed directly by the Pusgillian. South of Bala the limestones disappear, and at Corris the horizon is followed by black shales with

[1] A comparable break at the base of the upper Longvillian is found in Skåne, and, I think, in parts of Esthonia and the central basin of Tennessee.

Dicranograptus clingani (Nod Glas shales) (Pugh, 1929). Elsewhere, as at Aberllefenni, Meifod, Welshpool and round the Berwyns, there is a similar development of black shales usually with a phosphate bed at the base, but in these areas the Nod Glas is of post-Longvillian age. The highest Longvillian horizon is thus represented by an hiatus in many of the Welsh areas.

Marshbrookian.—In both East Shropshire and Westmorland the upper Longvillian facies continue into the Marshbrookian. In the former they are represented by the upper Longville flags, and in the latter by tough, calcareous mudstones below, and by dark grey shales in the highest zone. Outside these areas typical Marshbrookian faunas are unknown.

In North Wales the stage may be represented by a Nod Glas facies or entirely absent as at Bala. In South Wales the Robeston Wathen limestone may be of this age.

Actonian.—In East Shropshire there is a marked change above the Marshbrookian, the sediments changing to a light-grey colour with a prevailing calcic facies. The beds are calcareous, sandy mudstones with thin limestones, the types merging, and forming a more or less definite limestone member in the upper half.

In North Wales and Westmorland the Actonian is represented by black shales and thin dark limestones (Nod Glas facies) which at Dufton yield the characteristic Actonian faunas. In the Girvan district the Actonian and Onnian are represented in the series of grey flags with fossiliferous limestones underlying the zone of *Dicellograptus complanatus* (Pusgillian).

Onnian.—A well-developed Onnian fauna has been found only in East Shropshire and Westmorland. In the former area it comprises the calcareous mudstones with *Onnia* at the summit of the Acton Scott beds and the blue-grey sandy shales above. In the Dufton district the same fauna is found in the middle part of the Dufton shales between the Actonian and *Tretaspis* horizon (Pusgillian). The discovery by Shackleton of *Onnia gracilis* in the black shales of Welshpool suggests that these deposits and the black shales of Meifod and Aberllefenni include the Onnian.

In North Wales and Westmorland the Onnian is succeeded by blotchy blue and grey mudstones with *Tretaspis kjaeri*. These beds are of Pusgillian age. Locally, as at Bala, the Pusgillian includes a nodular limestone at the base.

Vulcanicity.—In this sketch I have made no reference to the important development of volcanic ashes which occur in the Upper Ordovician. Unlike the ashes of North America they do not occur as deposits of bentonite, but when the massive ashes thin out the ashy material is mainly disseminated through the sediments, or occurs as isolated pellets or balls. The thicker ash beds play an important part in the distribution of faunas across the disturbed muddy sea beds.

DESCRIPTION OF BRACHIOPODA

Superfamily DALMANELLACEA Schuchert and Cooper, 1931

Palaeontological Methods

Analysis of the rib system.—The analytic method adopted in this paper is that elaborated by the writer (Bancroft, 1928a). This method depends upon the fact that each element in the rib system can be correlated in all individuals, species, and genera in the superfamily. Certain ribs in the dorsal valve which extend to, or nearly to, the umbo are defined as primaries, and are denoted by the symbols, 1, 2, 3, 4 etc., 1 being the primary situated nearest to the mesial line. First branches on the *inner* side of the primaries are denoted by the symbols $1a^{-}$, $2a^{-}$, $3a^{-}$, etc., whilst the corresponding branches on the outer sides are $1a^{\circ}$, $2a^{\circ}$, etc. The first branches on the inner sides of these branches are denoted by $1a^{-1-}$, $2a^{-1-}$, etc., and the corresponding external branches by $1a^{-1\circ}$ and $2a^{-1\circ}$. The second and third ribs developed on the inner sides of primaries are denoted by the symbol for the primary followed by b and c respectively ($1b^{-}$, $1c^{-}$), and of these the first branches are $1b^{-1-}$, $2c^{-1-}$, etc. The same method is followed in representing ribs of higher order, the letters and numbers alternating in the formula, whilst each letter or number is followed by $^{-}$ or $^{\circ}$ according as it is developed on the *inner* side or *outer* side of its parent.[1]

The primaries are precisely defined with

[1] The *inner* side of a rib is always taken to mean the side facing the mesial line.

reference to a standard form, *Onniella brŏggeri.* The genetic equivalents of the primaries in that form always bear the same symbols: this principal is followed irrespective of their relations in a particular species or individual. As a matter of experience, however, it may be said that the mutual relations of the primaries are fairly constant in the Dalmanellidae and Harknessellinae. In the Dalmanellidae these relations are as follows:

1 arises very near the umbo on the side of 2. Unless the material is very well preserved it may appear to be independent of its parent.

2, 3, 4 and 5, and 6 and 7 when present, arise at the umbo.

1 and 2 together form a branching system as large or somewhat greater than that formed by 3 (sector III) or 4 (sector IV).

4a° arises early on the outer side of 4, and often appears to arise at the umbo. It forms a narrow sector between the larger IV–4A° and V.

Sectors I, II and part of III lie inside the mesial furrow; IV is partly on the top, or wholly on the outer flank of the obscure lateral fold.

This constitutes the *Onniella* facies.

In other groups the positions of the primaries may be somewhat different, but they seem fairly constant throughout the subfamilies I have investigated.

Statistics of the rib system.—The second step in the elaboration of the instrument depends upon the fact that rib branches appear at different stages in development. If a certain rib appears before another the symbol) is placed between their respective symbols. Thus 3a⁻1⁻a⁻) 3a° means that 3a⁻1⁻a⁻ originates before 3a°. In one application of the method we study the proportion of counts in which one rib appears before another. Thus if we write 3a⁻1⁻a⁻)3a°: 70 we mean that 3a⁻1⁻a⁻ appears before 3a° in 70 percent of the counts. For the sake of rapid comparison the percentages may be conveniently classified as in Table I.

Where the counts are too small to be relied upon the *indicated* proportion may be enclosed in brackets, thus [H]. H[3] would indicate that the proportion must be in H, and that indicated by the data is in H3.

Applications of the notational method to diagnosis.—The applications of the notational method to diagnosis include:

1, Statements descriptive of the general type and fineness of the ribbing. These consist of a list of the ribs terminating at the margin of the shells. For the sake of brevity all parent ribs may be omitted from these statements, as in the following list of last derivatives in III of a typical *Onniella:*

3a⁻1⁻a⁻, 3a⁻1°, 3b⁻1⁻, 3c⁻, 3a°.

2, Statements of the proportions in which one rib appears before another. The ribs may be selected from the same or from different sectors, and usually are chosen from I–IV. So far about 60 different relations have proved useful in the examination of Dalmanellacea. In the Harknessellinae 4a° is often difficult to determine, so that in this group the relations have been selected from I, I, III and IV–4A°.

TABLE I

66–100 percent	H	H3	88–100
		H2	77– 88
		H1	66– 77
33–66 percent	M	M3	55– 66
		M2	44– 55
		M1	33– 44
0–33 percent	L	L3	22– 33
		L2	11– 22
		L1	0– 11

In the diagnosis of species we may ignore all relations that are characteristic of the genus.

Classification of the Dalmanellacea

Schuchert and Cooper (1932) subdivide the Dalmanellacea into nine families of which the Dalmanellidae, Wattsellidae and Heterorthidae embrace the great bulk of Upper Ordovician genera. The separation of the Dalmanellidae and Wattsellidae was based upon the structure of the crural plates, the genera having fulcral plates being placed in the Wattsellidae, whilst those in which these structures are absent were referred to the Dalmanellidae. The presence of fulcral plates in immature individuals of certain Dalmanellidae detracts greatly from the merits of this classification, and it is further impaired by the fact that those

structures persist in certain individuals of species which have normally the *Dalmanella* type of crural plate. Even on an artificial basis the classification is, therefore, unsatisfactory. On the other hand, if *Horderleyella* were removed from the Wattsellidae, the Dalmanellidae and Wattsellidae of Schuchert and Cooper would constitute a natural family. Before discussing the relations of these families it is necessary to enquire into the affinities of *Horderleyella*.

Horderleyella is related to the Harknessellinae, and differs from the Wattsellidae and Dalmanellidae in the following characters:

1, The general form of the valve. Here we note the relative convexity of the dorsal valve, the long hinge, the presence of small posterolateral wings, the more or less conspicuous mesial fold on the ventral valve, and the well-defined lateral folds on the dorsal.

2, The general character of the ribbing and notably the large sector III forming the axis of the mesial fold.

3, The dorsal muscle pits, which extend posteriorly, forming cavities in the notothyral platform.

According to Schuchert and Cooper, on the other hand, *Horderleyella* differs from the Harknessellinae, and agrees with the Wattsellidae, in possessing fulcral plates. It has been found, however, that fulcral plates are present in the immature shells of all the harknesselline genera except *Smeathenella*, and in some species they persist in mature individuals. The sole ground upon which *Horderleyella* was removed from the Harknesellinae and placed in the Wattsellidae is shown, therefore, to be unsound. What support does the study of the rib system afford to this conclusion?

In Table II I have set out certain relations which are constant or nearly constant in the individual genera of the Harknessellinae, Dalmanellidae and Wattsellidae, and which at the same time serve to discriminate between two or more of these groups.

Examination of this table will show that the Dalmanellidae and Wattsellidae agree in all the relations that are consistent within the individual genera; *Horderleyella*, on the other hand, agrees in some characters with the Harknessellinae and in others with the Wattsellidae and Dalmanellidae: in these respects it occupies an intermediate position between the latter families and the Harknessellinae. Now this is precisely the result that is obtained from the study of other characters, which in the main are quite independent of the ribbing: in *Horderleyella* the general form and internal characters, whilst conforming to harknesselline types, do approach more nearly to the dalmanelloid types than the other, and in the main, later Harknessellinae. We may conclude, therefore, that *Horderleyella* ia a primitive harknesselline, probably derived in a dalmanelloid stock and ancestral to the other Harknessellinae. We may now return to the Dalmanellidae and Wattsellidae from which we shall assume that *Horderleyella* has been removed.

TABLE II

	Upper Ordovician species	3a⁻1⁻)3a°	3b⁻)3a°	3a°1°a°)3a°1⁻	4a⁻1⁻)3b°
Dalmanellidae	*Dalmanelle rogata*	H	H	L	H
	Onniella spp.	H	H	L	H
	Resserella spp.	H	H	L	H
Wattsellidae	*Wattsella* spp.	H	H	L	H
	Raymondella spp.	H	H	L	H
	Horderleyella, 4 spp.	M, [L]	L–M1	L	H
Harknessellinae	*Harknessella*, 3 spp.	L	L	L–H	H–[M]
	Reuschella, bilobata group, 8 spp.	L	L	H	L
	Reuschella, horderleyensis group, 8 spp.	L	L	M–H	L

The Dalmanellidae and Wattsellidae exhibit some 12 relations in the rib system which are invariable or very nearly invariable in both families; on the other hand, there is no single ribbing character that serves to discriminate between these groups. The general character of the ribbing and the mutual relations and position of the primaries also belong to a broadly defined facies which is not found in other groups. As to the other characters in these families, they also belong to the same facies: they present the same dalmanelloid form, the same types of muscle scars, the same types of cardinalia—the only character upon which their separation seemed possible is shown to have no classificatory value. These families, therefore, should be united.

Dalmanellidae

The British genera from the stages Costonian–Onnian are mainly distributed among the following genera: *Wattsella*, *Raymondella*, *Soudleyella*, *Resserella*, *Onniella* and *Heterorthina*. With the possible exception of *Heterorthina* all these genera exhibit a *Wattsella* stage (i.e. have fulcral plates) either in their phylogeny or ontogeny. *Wattsella*, in which the fulcral plates normally persist to maturity, may be regarded as the parent genus of the others.

The ribbing relations which are constant or nearly constant in these genera are the following:

2a^{-1-})2b^{-}:L, 2b^{-})2a°:H, 2a^{-1-})2a°:H
3a^{-1-})3b^{-}:H, 3b^{-})3a°:H, 3a^{-1}°)3a^{-1-a-}:L
4a^{-1-})4b^{-}:H, 4b^{-})4b°:H, 4a^{-1-a-})4b^{-1-}:H, 4a^{-1-a-})4a^{-2-}:H
4a^{-1-a-})4b°:L, 4a°2^{-})4a°1°:L
4a°1°)4a°1^{-a-}:H, 4a°1°)4a°1^{-}:L

The relations which help to discriminate between the genera are set out in Table III.

Genus WATTSELLA Bancroft

Wattsella BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 55.

Genotype, *Wattsella wattsi* Bancroft.

Generalized dalmanelloids with moderately high ventral valve and deep or moderately deep dorsal valve. Crural plates cavernous, with short, more or less transverse fulcral plates and strongly developed, converging supporting plates, the latter forming subparallel or anteriorly converging slots in moulds. Dorsal muscle area without strongly defined transverse ridges or angulated contour. Ventral valve with subcordate muscle area gently bilobed in front,

TABLE III

	2b^{-1-})2a°	2c^{-})2a°	3a^{-1-a-})3a°	3c^{-})3a°	3a^{-1}°)3b^{-1-}	4b^{-})4b°	4c^{-})4c°	4a^{-1}°)4a^{-1-a-}	4a^{-1}°)4b^{-1-}	3a^{-1-a-})2a^{-1-}
Soudleyella	L	L	L	L	L–M	M	L–M	M–H	H	M–H
Onniella Progressive	H	H–M	L–M	L	L	L	L	M	H	H
Onniella Early spp.	L	L	L	L	M	L	L	H	H	L–M
Wattsella Normal	L	L	L	L	M	L	H	L–M	H	L
Wattsella Progressive	H	H	M–H	H	L	M–H	H	L	L	L
Raymondella	H	H	H	H	L	[H]	[H]	L	L	L
Resserella, s. s.	[H]	M–H	M–H	M–H	L	H	H	L	L–M	
Ressellera (*Howellites*)	L–H	L–H	L–H	L–H	L	M–H	H	L	L–M	M

without vascular sinuses. Ribbing relations normally as in *Onniella*, with freely developed externals, approaching *Resserella* type in progressive stocks.

Observations.—On account of the magnitude and indefinite restriction of this genus it is much more difficult to diagnose than its more finely drawn derivatives. This task, however, becomes progressively lighter as the specialized species are assembled into new genera. If we ignore the progressive forms the genus can be recognized by three salient characters: the rather deep dorsal valve, the rather coarse ribbing with *Onniella* relations, and the characteristic crural plates. The latter character is often obscured by the filling in of the crural pits in individuals which are otherwise quite normal. When this takes place the traces of the supporting plates are no longer distinguishable in internal moulds, the entire structure forming a single triangular slot with the apex in front.

The types of crural plate found in the other genera can be derived from the *Wattsella* type as follows:

1, The angle between the socket lines becomes more acute. This leads to the suppression of the crural pit and the partial resorption of the fulcral plates and supporting plates in a pair of massive crural plates. With further thickening and growth in an anterior direction the crural plates assume the type found in *Resserella*, in which the fulcral plates and socket plates are entirely resorbed (*Dalmanella*, *Soudleyella*, *Resserella*, *Onniella*).

2, The fulcral plates are strongly developed and widely divergent, and the supporting plates are very short. The crural pit may be entirely filled with adventitious deposit giving rise to the massive and very widely divergent type of crural plates found in *Raymondella*.

The cardinal process and muscle scars of both valves are highly variable structures, occasionally reproducing the forms which are typical of other genera. This is found in species in which the crural plates have their most characteristic expression, so that little importance can be attached to these characters.

WATTSELLA HORDERLEYENSIS
Bancroft. n. sp.

Plate 22 figures 1–3; plate 23, figures 1–3; plate 24, figure 1

Coarsely ribbed shells, about 17 mm. wide. Dorsal valve deep, with shallow sinus; ventral valve moderately high. [3a⁻1⁻a⁻], 3a⁻1⁻, [3b⁻1⁻], 3b,⁻ [3c⁻], 3a° at periphery.[1] 3b⁻)3a°:H; 3a⁻1⁻a⁻)3a°:M; 3c⁻)3a°:L; 3a⁻1⁻a⁻)3b⁻1⁻:M. Inter-ribs present. Interiors of valves strongly ribbed. Crural plates with strong supporting plates, forming long slots in moulds. Muscle scar in dorsal valve shallow, with obscure transverse partition, periphery defined by weak boundary ridge or internal ribs.

Variation.—The variation in this species is most evident in the depth and definition of the muscle areas and the size of the bilobed myophore in the dorsal valve. The crural plates also are subject to variation, which arises partly from the variation in the curvature of the dorsal valve whereby they may be shortened, and partly from the partial filling in of the cavities.

In the large cognate forms from Welshpool[2] the ventral muscle area approaches the type found in *Resserella*, and, as in that genus, it is associated with vascular tracks; the dorsal valve also exhibits strongly defined muscle scars, but the crural plates are

[1] The brackets signify that the rib is sometimes very fine or absent.

[2] From the quarry by the cottage 200 ft. northwest of Fron y Fele; here it is associated with *Rafinesquina expansa* and *Resserella canalis*.

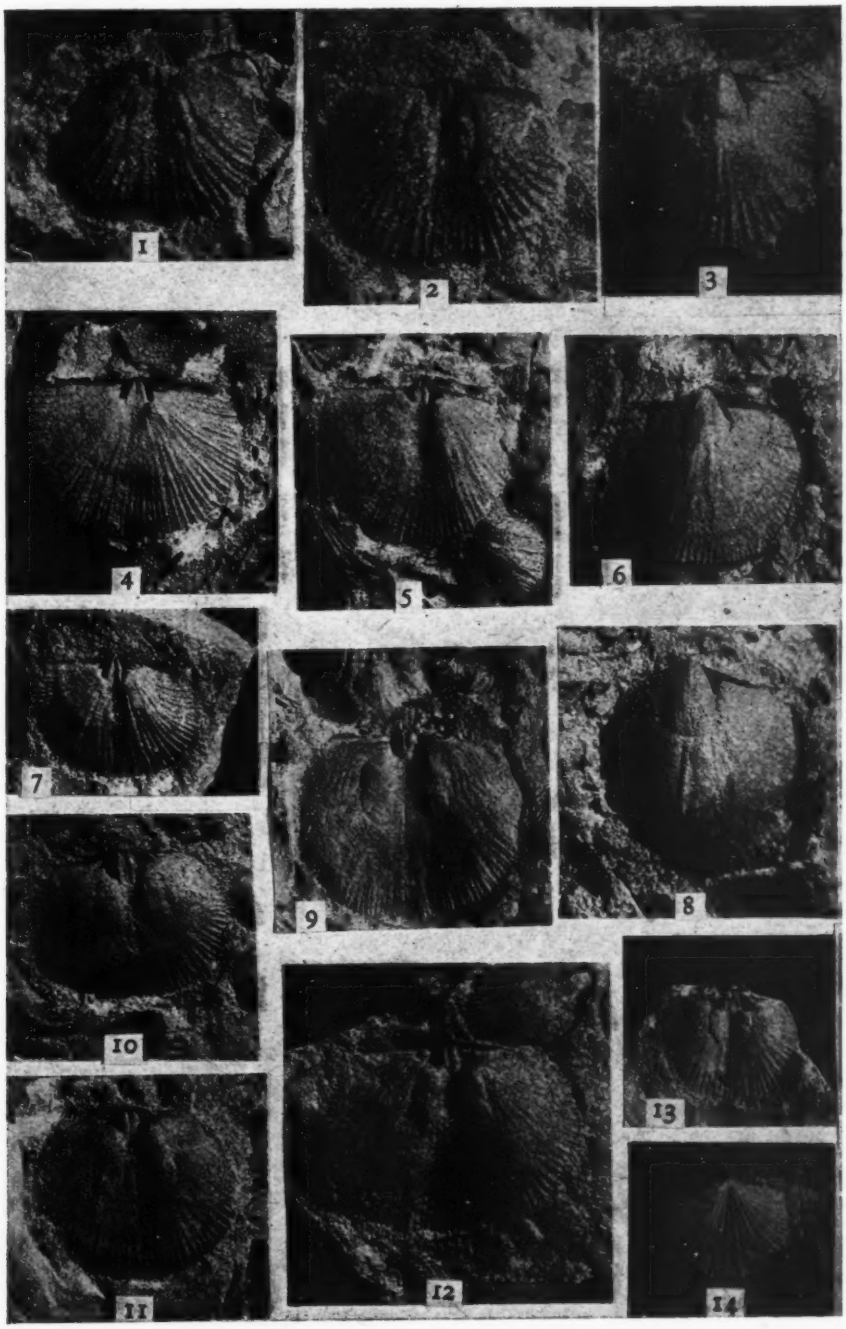
EXPLANATION OF PLATE 22

FIGS. *1–3*—*Wattsella horderleyensis* Bancroft, n. sp. *1*, *2*, Internal moulds of dorsal valves ×2; *3*, internal mould of ventral valve ×2; all from the type locality near Horderley, Southeast Shropshire. (p. 190)

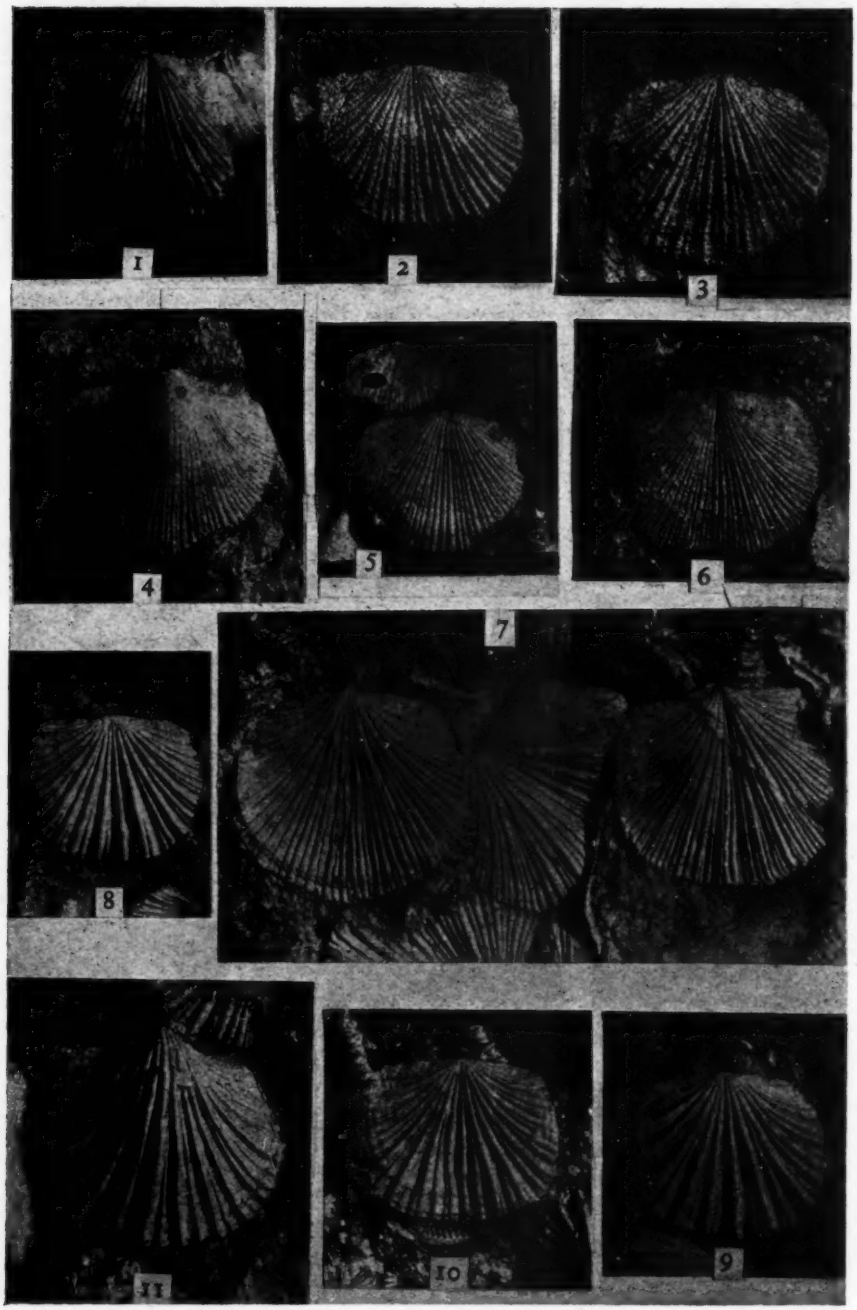
4–7—*Wattsella lepta* Bancroft, n. sp. *4*, *5*, Internal moulds of dorsal valves, ×2; *6*, internal mould of ventral valve, ×2; all from the type bed, Horderley, Shropshire. (p. 193)

8–12—*Wattsella indica* Bancroft, n. sp. *8*, Internal mould of ventral valve, ×2; *9–12*, internal moulds of dorsal valves, ×2; all from the type band, Horderley, Shropshire. (p. 194)

13, *14*—*Soudleyella avelinei* Bancroft. *13*, Internal mould of dorsal valve, ×2; *14*, cast from external mould of dorsal valve, ×2; both from the Glenburrell beds of Horderley, Shropshire. (p. 210)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

quite characteristic of *Wattsella*. These forms, which vary considerably in their convexity and the fineness of their ribbing, are referred to distinct species, but are nevertheless most intimately related to the *W. horderleyensis* stock.

The most marked variation in the ribbing relations is found in 2a⁻1⁻)2b⁻ which is low in the Welshpool and Meifod specimens, and high, or moderately high, in the types from Horderley.

longs to a group of species that range from the highest zone of the Soudleyan to the Marshbrookian. These species are all coarsely ribbed, and exhibit the freely developed externals characteristic of the genus. From contemporaneous progressive species they are distinguished by the absence or late development in the latter of many of the external ribs in sectors I–III, and by the finer type of ribbing in those species. From the earlier, Costonian and Harnagian forms

TABLE IV

	1a⁻1⁻)1b⁻	2b⁻)2a°	2c⁻)2a°	3b⁻)3a°	3c⁻)3a°	3a⁻1⁻)1a⁻	3a⁻1⁻a⁻)2a°
Wattsella horderleyensis	M-H	H3	L-M	H3	L		M3-H
W. sp., Welshpool 15b2	L	H[3]	L	H2	L		M3-H
Wattsella wattsi	L	M3-H1	L	M	L1	L1	M2
Wattsella unguis			H	H1-2	L[2]	M-H	L

Type locality and horizon.—The type specimens are from the fossil bed (1 ft.) in grey sandstone, 46 ft. above the base of the Longlane quarry, south of Horderley. The horizon is in the *Wattsella horderleyensis*—*Kjaerina* zone of the lower Longvillian.

Distribution.—*Wattsella horderleyensis* is confined to the zones of *Dinorthis multiplicata* and *Wattsella horderleyensis* and *Kjaerina*. It occurs abundantly at these horizons at Meifod in Montgomeryshire, and at the higher horizon in East Shropshire. It also occurs at Glyn Ceiriog, Welshpool and Bala in North Wales and possibly in Westmorland.[1]

Affinities.—*Wattsella horderleyensis* be-

[1] In the Alston Road section, east of Melmerby.

they are distinguished by their conspicuously larger size.

Inside the *Wattsella horderleyensis* group *W. unguis* is distinguished by its unusually few, plicate ribs, *W. wattsi* by its larger size and *W. horderleyensis* by its strongly convex dorsal valve. The main distinctions observed in the ribbing relations are set out in Table IV.

Associated fauna.—*Wattsella horderleyensis* is always associated with *Resserella canalis*, *Sowerbyella soudleyensis*, a large, subquadrate *Cliftonia*, and a large *Leptaena*.

WATTSELLA LEPTA Bancroft, n. sp.
Plate 22, figures 4–7; plate 23, figure 4

Valves about 15 mm. wide, finely ribbed for the genus. Hinge nearly as wide as shell

EXPLANATION OF PLATE 23

FIGS. *1–3*—*Wattsella horderleyensis* Bancroft, n. sp. Casts from external moulds of dorsal valves, ×2; from the type locality, near Horderley, Shropshire. (p. 190)

4—*Wattsella lepta* Bancroft, n. sp. Cast from external mould of ventral valve ×2; from the type band, Horderley, Shropshire. (p. 193)

5, 6—*Wattsella indica* Bancroft, n. sp. Casts from external moulds of dorsal valves, ×2; from the type band, Horderley, Shropshire (W71c). (p. 194)

7—*Wattsella wattsi* Bancroft. Casts from external moulds of dorsal valves, ×2; from the quarry in Marsh Wood, Marshbrook, Shropshire. (p. 195)

8–11—*Wattsella unguis* J. de C. Sowerby. *8–10*, Casts from external moulds of dorsal valves, ×2; *11*, cast from external mould of ventral valve, ×2; all from the *Wattsella unguis* zone of the quarry in Marsh Wood, Marshbrook, Shropshire. (p. 196)

Dorsal valve moderately convex for the genus, with shallow sinus. Crural plates usually with short longitudinal extension in mature individuals, and crural pits shallow. In young individuals crural pits well developed, and crural plates with characteristic form. Adductor scars usually obscure. Muscle area of ventral valve small, but strongly defined in most mature individuals. Interiors of valves finely ribbed, or internal ribbing restricted to narrow peripheral zone.

Ribbing relations.—In the absence of mature dorsal exteriors we are unable to define either the fineness or interrelations of the ribbing. It is quite clear, however, that the ribbing exhibits a progressive character. The following is an example of sectors I–III, in a young individual.

1)1a⁻
2)2a⁻)2a⁻1⁻
3)3a⁻)3a⁻1⁻)3b⁻)3a⁻1⁻a⁻)3a⁻2⁻)3b⁻1⁻)3c⁻.

Type locality and horizon.—The type specimens are from the fossil bed at the top of Rookery Wood, Horderley (Bancroft. Coll: P17FB1). The horizon is precisely located in the following section:

	Feet
Medium-dark, and light-grey sandstone	
Fossil beds (FB1) with *Wattsella lepta*	5
Pale grey sandstone	5
gap	c. 15
Dark grey sandstone	10
Green and purple banded sandstone	12
Buff and purple banded sandstone in small quarry	17.5
Blue flaggy sandstone (base of section) with *Dinorthis multiplicata*	1.5

Distribution and associates.—The species is restricted to the *Wattsella lepta* zone. It has been found at Horderley and Meifod, at both of which localities it is associated with *Kjaerina hedstroemi* and *Cliftonia* cf. *C. spiriferoides*. It is probable that some of the small finely ribbed shells from above the *Wattsella horderleyensis* horizon at Bala are also referable to this species.

Affinities.—This is one of the most finely ribbed of the lower Longvillian species of *Wattsella*. The long hinge and frequent occurrence of shells with strongly defined internal ribbing relate it to *Wattsella horderleyensis* from the subadjacent zone, and distinguish it from *W. indica* from the succeeding horizon. The progressive character of the ribbing may suggest affinity with the latter species. It differs from both these species in the feeble development of its internal structures, and on this account it seems clear that there is no close genetic affinity between them.

WATSELLA INDICA Bancroft, n. sp.
Plate 22, figures 8–12; plate 23, figures 5, 6

Shells rather finely ribbed for genus, 14.5–17 mm. wide. Width of hinge much less than width of shell. Dorsal valve moderately convex, with shallow sinus, or sinus obscure except in early growth-stages. [3a⁻1⁻a⁻1⁻], 3a⁻1⁻a⁻, [3a⁻1⁻b⁻], 3a⁻2⁻, [3a⁻1°], [3b⁻1⁻a⁻], 3b⁻1⁻, [3b⁻2⁻], [3c⁻1⁻], 3c⁻, [3d⁻], [3a°] at periphery. 2b⁻1⁻)2a°:H, 2c⁻)2a°:H, 3a⁻1⁻a⁻)3a°:H2, 3b⁻1⁻)3c⁻:M–H, 3a⁻1°)3b⁻1⁻:L1, 3a⁻1⁻a⁻)2b⁻:L1, 4b⁻)4b°:M, 4a°2⁻)4a°1°:L, 4a°1°)4a°1⁻a⁻:H.

Crural plates with short supporting plates, and crural pits partially or completely filled with deposit, or with normal characters of the genus. Cardinal process slender. Dorsal muscle area with subequal anterior and posterior scars, deeply impressed; boundary ridges weak or absent. A fine mesial vascular track sometimes present in ventral valve. Internal ribbing in both valves restricted to peripheral zone.

Variation.—The form in this species varies from types with rather short hinges and well-rounded contours, to long-hinged, transverse forms, an intermediate type being most common. The following are measurements of three dorsal valves: Length, 13, 12.5, and 11.5 mm.; width, 15.5, 14.5, and 14.5 mm.; width of hinge 9, 9, and 10 mm.

The variation in the ribbing embraces types with 3a⁻1⁻a⁻, 3a⁻2⁻, 3b⁻1⁻, 3c⁻ as ribs of highest order, and the finely ribbed forms with derivatives of these ribs (3a⁻1⁻a⁻, 3b⁻1⁻a⁻, etc.). In the most finely ribbed shells some of these derivatives are quite conspicuous ribs; but in most shells they are either very slender or in part absent.

Of the internal characters the most variable are the crural plates, which present every gradation between the typical *Wattsella* type and a type in which the supporting plates are nearly entirely resorbed. Natural moulds of the latter type appear as quite short triangular pits without any trace of

the slots characteristic of *Wattsella*. When the fulcral plates are well developed they approximate closely to the type found in *Raymondella*.

Type locality and horizon.—The type locality is in the small quarry 59 yds. from the northeast corner of Longville Plantation, by the side of a track through the plantation. The type band is the highest shell bed exposed at the northeast corner of the quarry (Bancroft Collection: W71c). *Wattsella indica* occurs in profusion in all the pink-stained shell beds in the quarry. The section is as follows:

	Feet
Sandstone at top of quarry	1
Fossil-band (W71c)	
Green sandstone	1.8
Lenticular fossil-beds passing out together between bedding planes (W71b1–b4)	(2)
Green sandstone	1.5
Fossil-bed	0.2
Green sandstone	2.2
Green and purple bedded sandstone	2.8

The entire quarry is in the zone of *Wattsella indica*.

Associated fauna.—At the type locality the associated fauna includes *Dalmanitina apiculata*, *Resserella* aff. *R. canalis*, *Dolerorthis*, *Kjaerina* sp. and a longitudinally striate *Tentaculites*.

Distribution.—Identical or closely similar shells occur in the section at Bryn in the Glyn Ceiriog district, and about 45 feet below the crystalline limestone at Bala.

Affinities.—The rib system in *Wattsella indica*, with its even character and suppressed externals, approaches the type found in the later *W. multiplicata* and the genera *Raymondella* and *Resserella*. A comparison of the ribbing relations suggests a position intermediate between these forms and the earlier *W. horderleyensis*. As far as *W. multiplicata* is concerned this may be true, but the study of the general characters of *W. indica* and *Raymondella typa* rules out the possibility of close genetic relationship: here the affinities of the ribbing relations are due to convergence.

WATTSELLA WATTSI Bancroft, 1928

Plate 23, figure 7; plate 24, figures 2–5

Wattsella wattsi BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 58, pl. 1, figs. 1–5.

Shells large, up to 23 mm. wide, coarsely ribbed. Dorsal valve weakly convex with broad, shallow mesial sinus, or mesial sinus indistinct. 3a^{-}1^{-}a^{-}, [3a^{-}1°], 3b^{-}1^{-}, 3c^{-}, [3a°1^{-}], 3a° terminal. 1a^{-}1^{-})1b^{-}:L, 2b^{-})2a°:M–H, 2c^{-})2a°:L, 3b^{-})3a°:M, 3a^{-}1^{-})1a^{-}:L, 3a^{-}1^{-}a^{-})3a°:L1. Interspaces between ribs with concentric striae; interribs absent. Crural plates of normal *Wattsella* type, but usually with rather short supporting plates, Cardinal process with long shaft and small myophore. Dorsal muscle scars normally obscure, traversed by internal ribbing, without transverse partition. Ventral muscle area strongly defined, bilobate; divaricator scars distinct, produced in front of adductor area. Interiors of both valves more or less strongly ribbed.

Variation.—The form varies between a more or less rounded type and a transverse type with short hinge; large gerontic individuals usually present the latter form. In the rib system 3a^{-}1^{-}a^{-}, 3b^{-}1^{-} and 3c^{-} are always terminal and without derivatives; in this species, however, III is a rather narrow sector, and its terminals do not reflect the relative fineness of the ribbing or the amount of variation. In sectors of this kind the earlier branches may originate within a wide range of growth stages, and when their appearance is delayed the ribs of higher order may appear together suddenly near the periphery. In this way there arises a variety of relatively coarsely ribbed shells with more finely ribbed peripheral zones, which contrast with the more finely and more evenly ribbed types.

In the interior of the dorsal valve the variations arise largely from the variable development of the internal ribbing. This is rarely strongly defined in the vicinity of the muscle area.

In the ventral interior the divaricator scars may enclose the adductor area or the latter may be open at the front. Here again the boundary of the scars may be obscured by the presence of internal ribbing.

Type locality and horizon.—In the *Wattsella wattsi* zone of the old quarry in Marsh Wood, half a mile south of Marshbrook Station, Southeast Shropshire. The upper half of the section in the northwest corner of the quarry is formed by the *Wattsella unguis* zone; our type specimens were from just below this horizon.

Distribution.—*Wattsella wattsi* occurs in great abundance in the *W. wattsi* zone of East Shropshire; elsewhere it is known only in the lower part of the Dufton shales of Westmorland.

Associated fauna.—The fossils of the *W. wattsi* zone are in the main the same as those of the overlying horizon: *Bröggerolithus transiens, Brongniartella bisulcata, Chasmops macroura, Kjerulfina, Longvillia* and *Tentaculites anglicus.*

Affinities.—The ribbing suggests affinity with *W. horderleyensis* and the other forms with freely developed externals. A comparative table of the distinctive ribbing relations in this group is given under the description of *W. horderleyensis.* Here we may note that *W. wattsi* is distinguished from all other known forms by 3b⁻)3a°: M, this proportion being aberrant in the family. From the other Marshbrookian index, W. *unguis*, it is distinguished by the much finer character of its ribbing, and the proportions, 2c⁻)2a:[L], 3a⁻1⁻)1a⁻:L and 3a⁻1⁻a⁻)2a°:M2. Of the lower Longvillian forms *W. horderleyensis* is readily distinguished by its strongly convex dorsal valve; on the other hand the form from Welshpool 15b2[1] approaches *W. wattsi* both in its general characters and in its ribbing relations. As regards the latter characters it is noteworthy that the proportions suggest a possible line of descent, *W. horderleyensis*→*W.* sp. (Welshpool 15b2)→*W. wattsi.* This would be a retrogressive trend.

WATTSELLA UNGUIS (J. de C. Sowerby)
Plate 23, figures 8–11; plate 24 figures 6, 7

Terebratula unguis SOWERBY, 1839, in Murchison, Silurian system, p. 640, pl. 21, fig. 13.

Shell small to moderately large, with plicate ribbing. Dorsal valve weakly convex, with obscure sinus. [3a⁻1⁻], 3a⁻, [3a⁻1°], [3b⁻], [3c⁻], 3a° terminal. 2c⁻)2a°:H, 3c⁻)3a°:L, 3a⁻1⁻a⁻)2a°:L. Interspaces between ribs with concentric striae; interribs absent. Crural plates without crural pits, or crural pits only partially filled with adventitious deposit. Dorsal muscle scars shallow or obscure, sometimes with weak transverse partition. Ventral muscle area bilobate. Interiors of both valves strongly ribbed.

Variation.—The ribbing of this species is so remarkable that eminent palaeontologists have found difficulty in accepting it as a dalmanellid. However, the coarsely ribbed forms are linked by imperceptible gradations to types with clearly defined *Wattsella* characters. The following examples of sectors I–III are characteristic, but, I think, scarcely define the complete range of variation.

(1) 1a⁻, 1, 2a⁻, 2, 3a⁻1⁻, 3a⁻, 3.
(2) 1a⁻, 1, 2a⁻, 2, 2a°, 3a⁻1⁻, 3a⁻, 3b⁻, 3.
(3) 1a⁻1⁻, 1a⁻, 1, 1a°, 2a⁻2⁻, 2a⁻1⁻, 2a⁻, 2, 2a°, 3a⁻1⁻, 3a⁻, 3a⁻1°, 3b⁻, 3, 3a°.

The form of the shell varies from slightly transverse to conspicuously long, the latter form being referable to a distinct variety.

Type locality and horizon.—In the sandy mudstones of the *W. unguis* zone, in Marsh Wood quarry, as defined in the following section:

		Ft.	in.
Z1a35	Halfway up face at north end quarry: rotten red rock with *Heterorthina praeculta*	0	3
36	Mudstone with large *Wattsella unguis*	1	3
37	Fossil bed with *W. unguis, Kjerulfina*	0	2½
38	Mudstone, *Longvillia*	0	3
39	Rotten fossil bed, *W. unguis, Bröggerolithus*	0	3½
40–42	Mudstones, flaggy band, thin shaly bed	1	6¾
43	Laminated sandstone	0	6
44	Mudstones	1	0
	Gap	5	6
b1–4	Sandy mudstones, *W. unguis*	1	8
5–6	Laminated sandstone.		
7	Fossil band, *W. unguis*	0	2
8–12	Sandy mudstones, *W. unguis, Chasmops macroura, Bröggerolithus transiens*	1	8¼
13	Mudstone, *W. unguis, Kjerulfina trigonalis*	1	0
14	Mudstones, to top of section	4	0

Distribution and associated fauna.—The species has been recorded from East Shropshire and Westmorland, and less certainly

[1] Located in the following section through the lower beds in the old quarry above Trawscoed Rough, Guilsfield, Welshpool:

		Inches
15a	Low, long dip face at base of section.	
15b1	Just below, and to clean face in main section, fossil bed	8
15b2	Grey, flaggy hard band	7
15b3	Sandy beds	14
15b4	Hard grey flaggy bed	6
15b5	Coarse sandy bed	12
15b6	Hard grey, flaggy bed	9

from the Robeston Wathen limestone of Pembroke. At the former localities it is associated with *Bröggerolithus transiens* and *Brongniartella bisulcata*.

Affinities.—A closely similar form occurs in the lower Longvillian in the quarry at the foot of Gaer Fawr, Welshpool. The associates at this locality are *Bröggerolithus transiens*, var. and *Brongniartella bisulcata* together with a lower Longvillian fauna. This form differs from *W. unguis* in the absence of the coarsely plicate variations, but their general characters and faunal associates leave no doubt as to their relationship.

Genus RAYMONDELLA,[1] n. gen.

Genotype, *R. typa* Bancroft.

Valves long, with wide hinge. Immature shells shield-shaped. Dorsal valve feebly convex with very wide, shallow sinus. Ventral valve high. Ribbing even, progressive. 2b⁻1⁻)2a°:H, 3a⁻1⁻a⁻)3a°:H, 3c⁻)3a°:H, 3a⁻1⁻a⁻)2a⁻1:L, 3a⁻1⁻a⁻)2b⁻:L. Crural plates massive, short; supporting plates resorbed; socket lines long, widely divergent; pre-socket lines converging obtusely anteriorly. Muscle scars in dorsal valve variably impressed; anterior and posterior scars subequal; peripheral ridge weak. In ventral valve divaricator scars usually steeply inclined, narrow, not enclosing adductor area; obscure vascular tracks present. In both valves internal ribbing restricted to narrow peripheral zone.

Observations.—This is a narrowly restricted genus embracing a series of species from the lower and upper Longvillian. As defined by these forms the salient characters are the shallow dorsal, and high ventral valve, the peculiar crural plates, and the terminal ribbing relations. Half-grown individuals have a more or less shield-shaped contour usually represented in the mature shell by strong growth lines. This form often persists with some modification at maturity, though not infrequently the shell assumes a more transverse and *Wattsella*-like contour. There is also a considerable amount of variation in the convexity of the dorsal valve. On the other hand, the ribbing is consistently even and progressive, and varies only in fineness and in its statistical characters.

In very young shells the crural plates present the *Wattsella* type with distinct supporting plates and fulcral plates. This type, modified by partial resorption of the supporting plates, may persist in mature shells: in such individuals the structure resembles the most advanced type in *Wattsella indica*. In the majority of the shells, however, the filling of the crural pits is complete or nearly complete, and the supporting plates entirely resorbed. The most notable variations in the ventral valve affect the form of the muscle area, and particularly the relative proportions of the scars as seen in their ventral aspect. When the divaricator scars are steeply inclined (*Resserella* type) they appear as relatively narrow tracks when looked at from above; when they are less steeply inclined they seem much wider relative to the adductor area, and the muscle area approaches the type found in *Wattsella;* the adductor area, however, seems always to be open at the front.

Affinity with other genera.—*Raymondella* is distinguished from *Soudleyella, Onniella* and normal *Wattsella* by the terminal characters of its rib system, and especially by the ribbing relations set out in the comparative table (Table V). Here we may note: 2c⁻)2a°:H, 3a⁻1⁻a⁻)3a°:H, 3c⁻)3a°:H. From *Soudleyella* and *Onniella* the genus is further distinguished by the *Resserella*-like crural plates in those genera. No known ribbing relation serves to distinguish the genera *Raymondella* and *Resserella*, s. s. and progressive species of *Wattsella*. In separating these groups we rely mainly upon the characters in Table V.

From Table V it will appear that *Raymondella*, whilst approaching closely to *Resserella* in certain characters, has no close genetic relation to that genus. A much more closely related genus is the Silurian *Parmorthis*. In both *Raymondella* and *Parmorthis* the dorsal valve is shallow, and has a broad sinus, and in both the ventral valve is conspicuously high. Both have an approximately shield-shaped contour in young shells, and a rather coarse, terminal type of ribbing. The crural plates also have the same broadly defined type with fulcral plates. Of course there are notable differences: the

[1] After my brother, Mr. G. R. B. Bancroft, by whom the publication of these genera has been made possible.

ventral valve is higher, and the dorsal more shallow in *Parmorthis*. Again the muscle areas in both valves are highly specialized in that genus, and the crural plates more massive. But these transformations are such as we might expect in comparing a Silurian derivative with a Longvillian ancestor, and if we accept a generalized *Wattsella* as the ultimate source, they are unidirectional in character.

Raymondella embraces some four known species of which two are described in this paper, *R. typa* and *R. robusta*.

TABLE V

	Raymondella	*Resserella*, s. l.	*Wattsella*
Dorsal valve	*Raymondella* type: shallow with wide sinus.	Generalized type.	Generalized type.
Ventral valve	High.	High.	Moderately high.
Crural plates	*Raymondella* type: with obtusely convergent socket lines. Supporting plates resorbed.	*Resserella* type: Socket lines more acutely divergent. Supporting plates resorbed.	*Wattsella* type: with well-developed supporting plates.
Ventral interior	Approaching *Resserella* type. Vascular trunks feebly developed.	*Resserella* type: with strongly developed vascular trunks.	Generalized type: without vascular sinuses.
Ribbing	Variable, coarser than in *Resserella*.	Very fine.	Variable.

RAYMONDELLA TYPA Bancroft, n. sp.
Plate 25, figures 1–10

Small shells, 14–15 mm. wide. Shell with a conspicuously strong growth line forming shelf, or a group of growth lines; more rarely same weak or absent. Ribbing only moderately coarse or rather fine for genus. [3a^{-}1^{-}a^{-}1^{-}], 3a^{-}1^{-}a^{-}, 3a^{-}2^{-}, [3a^{-}3^{-}], [3b^{-}1^{-}a^{-}], [3b^{-}1^{-}b^{-}], 3b^{-}1^{-}, [3c^{-}1^{-}], 3c^{-}, [3a°] terminal. 1a^{-}1^{-})1b^{-}:L, 2a^{-}1^{-})2b^{-}:L, 2b^{-}1^{-})2c^{-}:M, 4a^{-}1^{-}a^{-})4b°:L1–2. Crural plates very short and wide or approaching columnar. Ventral interior *Resserella*-like, with narrow, steeply inclined divaricator scars and relatively wide adductor area; vascular trunks sinuous or absent.

Variation.—The variation in external form embraces the full range for the genus, including the rather long (normal), and transverse variants. In the former both valves are more or less conspicuously parmorthoid. A parmorthoid stage occurs in the development of most individuals, and is often defined by strong growth lines. In typical dorsal valves there is a conspicuously strong growth line forming a shelf between the middle of the shell and the periphery; besides this there may be 1–4 weaker growth lines; abnormally the growth lines may be obscure.

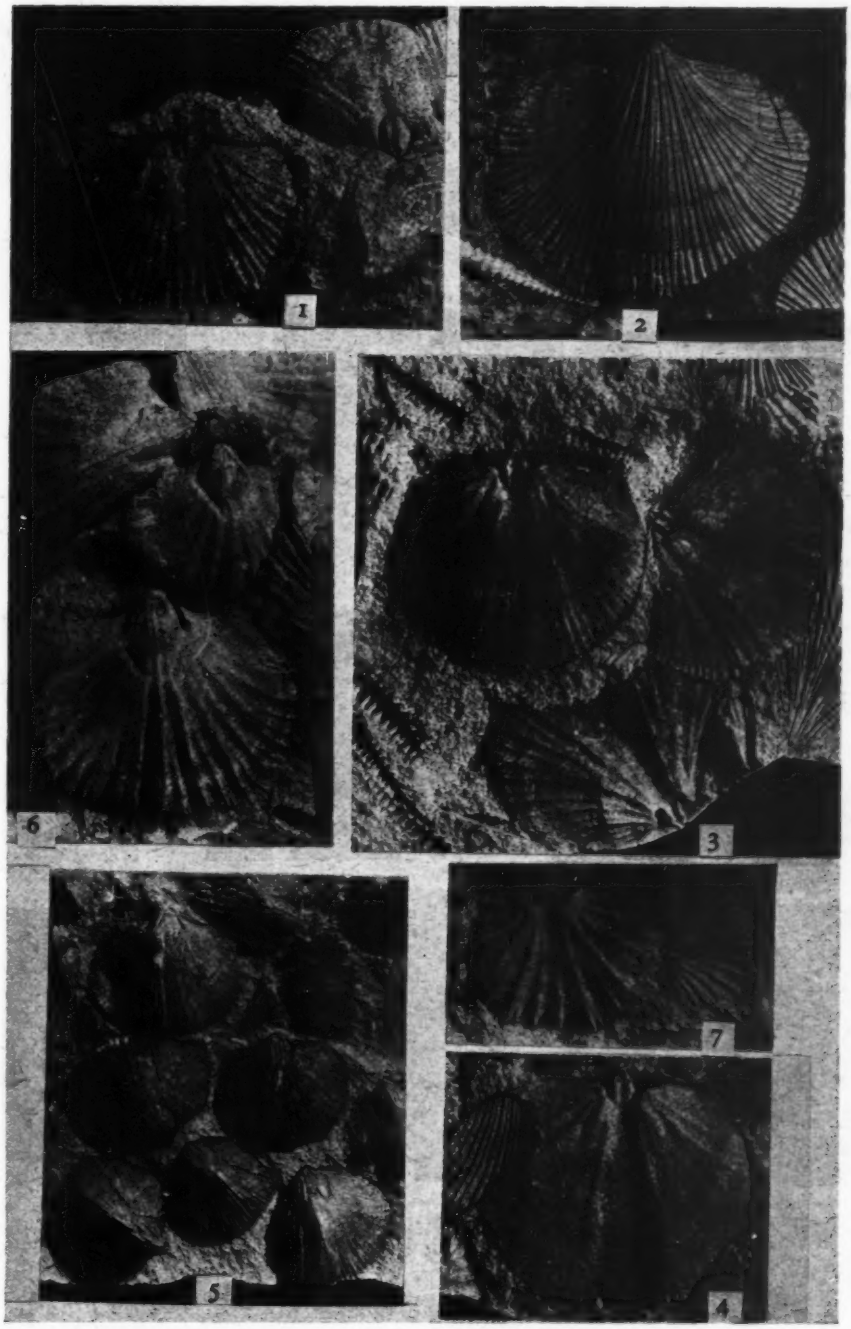
The internal characters in this species are always strongly expressed and strongly dif-

EXPLANATION OF PLATE 24

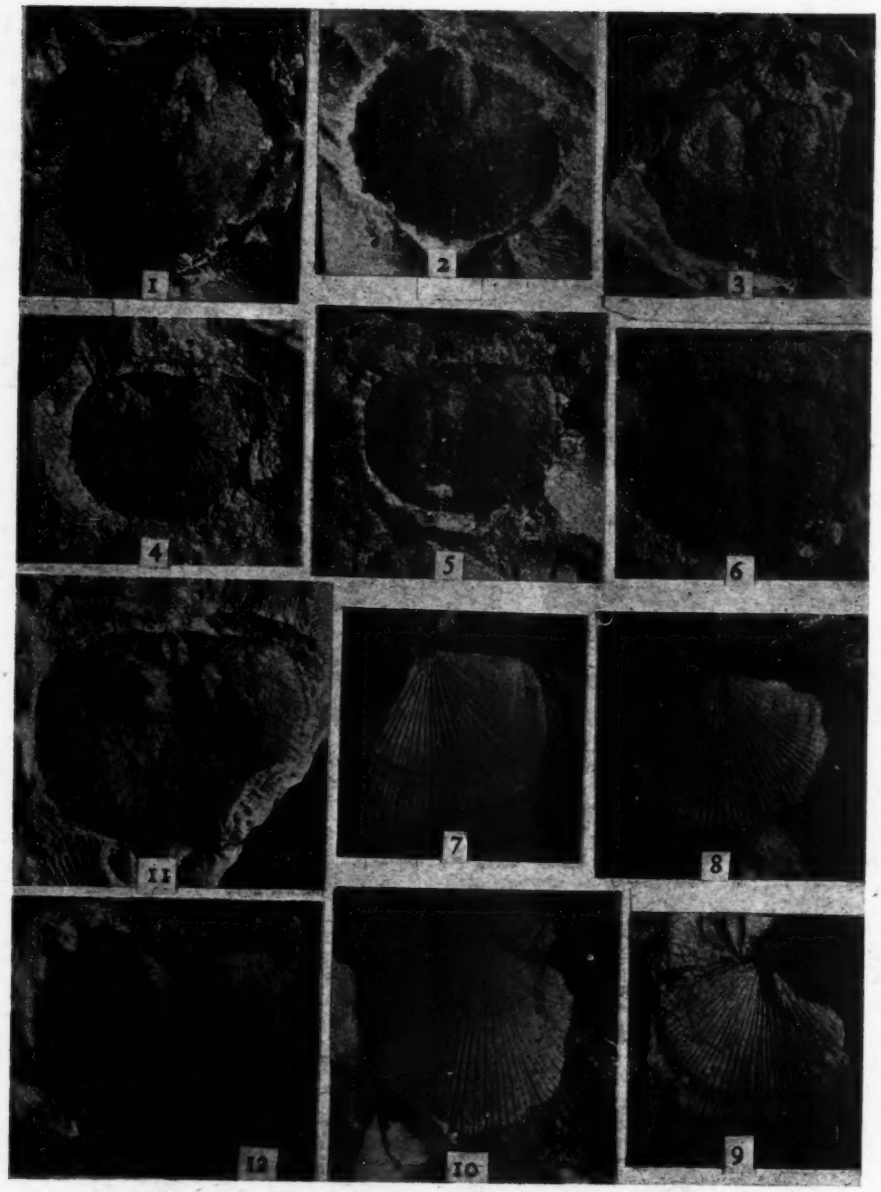
FIGS. *1*—***Wattsella horderleyensis*** Bancroft, n. sp. Internal moulds of dorsal valves ×2; from the type locality, near Horderley, Shropshire. (p. 190)

2–5—***Wattsella wattsi*** Bancroft. *2*, Cast from external mould of ventral valve, ×2; *3*, *4*, internal moulds of dorsal valves, ×2; *5*, internal moulds of ventral valves, ×1; all from the ***Wattsella wattsi*** zone of the old quarry in Marsh Wood, Marshbrook, Shropshire. (p. 195)

6, *7*—***Wattsella unguis*** (J. de C. Sowerby). *6*, Internal moulds of ventral valves, ×2; *7*, internal moulds of dorsal valves, ×2; both from the ***Wattsella unguis*** zone of the quarry in Marsh Wood, Marshbrook, Shropshire (Z1). (p. 196)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

ferentiated, and, apart from the crural plates and vascular sinuses, exhibit no important variations.

Type locality and horizon.—In the quarry by New House, Horderley, in the fossil bands in P15b as defined in the following section:

P15a Massive greenish sandstones with subordinate purple banding and mottling, forming the lower, and main, part of the section.
15b Green, rather flaggy sandstones with fossil beds, *R. typa*, *Sowerbyella*, *Brongniartella*, *Platylichas* aff. *laxatus*, 3 ft.
15c Green, flaggy beds at top of section.

The section is in the zone of *R. typa*, in the lower Longvillian.

Distribution and associates.—I have recorded this or a closely similar species from about 35 feet below the Crystalline limestone at Bala. The horizon is the same as in East Shropshire, and yields the Horderley associate, *Platylichas* aff. *P. laxatus*, together with a typically Welsh fauna.

Affinities.—*R. typa* is the earliest and smallest of the known representatives of the genus. The later forms are conspicuously larger, though in other respects closely similar to *R. typa*.[1] The affinities with *R. robusta* are noted in the description of that species.

RAYMONDELLA ROBUSTA Bancroft, n. sp.
Plate 25, figures 11, 12; plate 26, figures 1–3

Large, up to 22 mm. wide. Growth lines restricted to peripheral zone, weak. Ribbing moderately fine to coarse. [3a^{-}1^{-}a^{-}1^{-}], [3a^{-}1^{-}b^{-}], 3a^{-}1^{-}a^{-}, [3a^{-}2^{-}a^{-}], [3a^{-}3^{-}], [3b^{-}1^{-}a^{-}], 3b^{-}1^{-}, [3b^{-}2^{-}], [3c^{-}1^{-}], 3c^{-}, [3d^{-}], 3a° terminal. 1a^{-}1^{-})1b^{-}:L2, 2a^{-}1^{-})2b^{-}:M2, 3b^{-}1^{-})3c^{-}:M, 4a^{-}1^{-}a^{-})4b°:L3–M1. Dorsal interior with the characters normal to the genus, or with the dorsal muscle scars shallow, and with faint transverse ridges. Muscle area of ventral valve with divaricator scars broad, moderately steeply inclined and lobate, and adductor scar very narrow, or divaricator scars narrow and steeply inclined, and adductor scar relatively wide. Vascular sinuses usually obscure.

Variation.—The external form of the shell exhibits the variations that were noticed in *R. typa*, though the characteristic parmorthoid type is more conspicuously predominant. The ribbing, on the other hand, includes a much coarser type than we have noticed in *R. typa*. In this limiting form the terminals in III are 3a^{-}1^{-}a^{-}, 3a^{-}2^{-}, 3b^{-}1^{-}, 3c^{-}, 3d^{-} and their parents. In the more finely ribbed specimens all the above ribs with the exception of 3d^{-} may be parents with quite well developed derivatives.

The variations of the crural plates include types in which the supporting plates make short slots in the moulds. Abnormal variations are found in the muscle areas of both valves. In the dorsal the muscle scar is sometimes very shallow, without distinct partitions, and with the radial boundary ridge of the anterior scar produced into the posterior. Normally the divaricator scars of the ventral valve are wide, and have gently rounded sections as in *Wattsella;* they are produced into short, angular lobes in front, and show feeble differentiation; between these scars the adductor area forms a narrow track, which may continue in front of the muscle area as a mesial sinus. When the sides of the muscle area are more steeply inclined the ventral surface is traversed by two strong vascular tracks at the sides of the adductor area; the anterior extremities of these tracks may also be produced beyond the muscle area.[2] The adductor scar is much wider in this type.

[1] These facts have considerable stratigraphical importance. The large *Raymondella* occur suddenly in or just above the Crystalline limestone horizon at Bala and the Alternata limestone in Shropshire. This suggests a break at the base of the upper Longvillian.

[2] This type is characteristic of *Raymondella typa* and *Resserella*. It is an important feature in the *Resserella* type of ventral interior.

EXPLANATION OF PLATE 25

FIGS. *1–10*—*Raymondella typa* Bancroft, n. sp. *1, 2*, Internal moulds of ventral valves, ×2; *3–6*, internal moulds of dorsal valves, ×2; *7–10*, casts from external moulds, ×2; all from the type band, Horderley, Shropshire. (p. 198)
11–12—*Raymondella robusta* Bancroft, n. sp. Internal moulds of dorsal valves, ×2; both from the type band in the lane section at Woolston, Shropshire. (p. 201)

Type locality and horizon.—In the section in the lane east of the quarry at Woolston, Southeast Shropshire, 66 paces east of the quarry. The specimens are from two bands:

1, A sandstone fossil bed underlying a thin bed of shale, forming a 3-inch bed in the middle of the road, 14 feet from the 2-foot bed exposed in the middle of the road. Bancroft Coll.: Woolston 199.

2, A thin limestone band, 1 foot 6 inches below 1. Bancroft Coll.: Woolston 197½'.

The horizon is in the upper Longvillian about 70 feet above the summit of the Alternata limestone.

Distribution and associates. As I have defined this species it is known only from the East Shropshire district. It is, however, a member of a series of closely related forms, all of large size and characterized by the same general characters. Such forms occur at the summit of the Alternata limestone in Shropshire, and about 7 feet above the Crystalline limestone in the Bala country.[1]

The associates are quite different in the two areas: at Horderley they are mainly species of *Kjaerina*, *Sowerbyella* and, at the higher horizons, *Wattsella*. In the Bala district, where the species is much less conspicuous, it is associated with *Dolerorthis*, *Platystrophia* and *Chasmops conicophthalma*, all of which attain a large size at this horizon. It would appear that *Raymondella* is an invader from the east.

Affinities.—I have already noted certain affinities between this species and *Raymondella typa*, and have pointed out that the range of variation is nearly the same. The most important differences are: 1, The much larger size of *R. robusta*. 2, The absence of strong growth lines on the dorsal exterior of *R. robusta*, and their presence in *R. typa*. 3, The prevailingly shallow dorsal valve in *R. robusta*. 4, The broader, more gently rounded divaricator scars in *R. robusta*.

Besides these there are important differences in the ribbing relations, which are set out in the diagnoses.

The form from immediately above the Alternata limestone agrees much better with our species, the form and prevailing type of ventral muscle area being the same, whilst the shallow and deep types of scars are found in the dorsal valves of both forms. The shells from Bala also agree in size, but in the absence of an adequate amount of material it is impossible to make a close comparison with this species.

[1] In the long quarry, 1100 feet west of Gelli-Grin, at the top of the section (Bancroft Coll: Bala 19e). Here the horizon follows a bed with large leptaenoids.

Genera with the *Resserella* type of Crural Plate

I now come to a group of genera in which the crural plates conform to a single distinctive form, which I shall call the *Resserella* type. In the *Resserella* type the supporting plates and fulcral plates are resorbed into a pair of solid plates with long, rather narrowly divergent socket lines, and short, nearly transverse pre-socket lines. The distinctive features are best seen in the basal plan as exhibited by natural moulds. In these the crural plates form subtriangular cavities with the apical angles situated posteriorly, and the inner and outer sides of nearly equal length, whilst the anterior side is more or less transverse. This type of crural plate is found in *Resserella*, *Onniella*, *Soudleyella*, and *Dalmanella* as restricted by Schuchert and Cooper.

As the apical angle increases the crural plate assumes a more massive character, and the presocket lines lengthen and become more acutely convergent towards the front; they thus approach the type found in those individuals of *Wattsella* in which the crural pit is filled by adventitious deposit. In the earliest growth stages of many of my species there is a well-defined crural pit, and the crural plate is split up into the elements which characterize the mature *Wattsella*. In other forms the crural pit has not been discovered (*Resserella*, s. s.), but the youngest shells have the narrowly convergent presocket lines of *Wattsella*. The young shells of the immediate ancestors of these forms (*Howellites*) have well-defined fulcral plates and supporting plates, and traces of these elements may persist in mature shells. All these genera, therefore, are derived in the broadly conceived *Wattsella*.

Soudleyella appears in the Harnagian, the forms from that horizon exhibiting no trace of fulcral plates in the mature shell. *Res-*

serella, on the other hand, appears in the Soudleyan, and the earliest forms exhibit strong affinities with *Wattsella*. It is quite clear, therefore, that the *Resserella* type of crural plate affords no evidence of monophyly. The relations between these genera appear to be these: *Soudleyella* and *Resserella* were independently derived from *Wattsella*, and from *Soudleyella* arose the Actonian *Onniella*.

Genus RESSERELLA Bancroft, sensu stricto

Resserella BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 54.

Genotype; *Orthis canalis* Sowerby (1839, p. 640, pl. 13, fig. 12a).

Finely ribbed, lower Longvillian dalmanelloids with shallow dorsal and high ventral valve. Ventral valve with large, prominent beak. Shell long to moderately transverse, with wide hinge. Ribbing even progressive. 2c⁻)2a°:M-H, 3a⁻1⁻a⁻)3a°:M–H, 4c⁻)4c°:H, 4a⁻1°)4a⁻1⁻a⁻:L. Dorsal interior with crural plates of *Resserella* type, and muscle scars with sharply defined, transverse and peripheral ridges; anterior and posterior scars (normally) subequal. Dental plates strong, divergent. Ventral muscle area with narrow, steeply inclined divaricator scars; inner region of divaricator scars consisting of a pair of strong, diverging, vascular canals defining acutely triangular adductor area at the sides, adductor area more or less completely filled by strong vascular track, produced anteriorly beyond muscle area. Interior of ventral valve traversed by coarse, irregular sinuses. Internal ribbing restricted to peripheral zone.

Observations.—In the most characteristic shells the front of the ventral muscle area is not defined, the three main sinuses continuing into the middle region of the shell, where they may either bifurcate or die out. No general description can define the character of the sinuses in this part of the shell; they are at the same time so irregular, coarse and prevailingly indefinite, that it is by these facts rather than by their mutual relations that we must recognize the *Resserella* facies. There are, however, some noteworthy though by no means consistent characters. The adductor track often swells into a shallow fossa (hump in moulds) in front of the muscle area, and from this arise two more or less parallel branches. In some individuals, however, the fossa is absent, and the adductor track bifurcates shortly after leaving the muscle area. In others the main track continues anteriorly to near the periphery. The tracks arising in the divaricators may also reach the periphery without branching, or they may branch repeatedly. Negatively, this type of sinus system is characterized by the absence of fine and regular features.

To return to the ventral muscle area. When regarded in its ventral aspect it exhibits little more than the triangular area defined by the vascular trunks; at the sides of this area the surface rises steeply, often nearly vertically, towards the inner edges of the dental plates. The latter are a pair of strong divergent plates extending about halfway along the sides of the muscle area; at their anterior extremities arise the weak ridges that sometimes define the muscle area. The other characters in the subgenus are not known to exhibit important variations.

The restricted genus ranges through the highest zone of the Soudleyan and the overlying lower Longvillian as far as the base of the *Raymondella typa* zone. At these horizons it occurs abundantly throughout the North Wales-Shropshire region.

Resserella is distinguished from all other genera by the combination of three characters: the resserelloid type of crural plate, the strong vascular sinuses in the ventral valve, and its fine, even, and progressive ribbing.

No species of *Resserella*, s. s., are described in this paper.

Subgenus HOWELLITES Bancroft, n. subgenus

Genotype: *Resserella* (*Howellites*) *striata* Bancroft, n. sp.

Strongly convex dorsal valves. Ribbing varying from progressive type of *Resserella*, s. s., to type with freely developed externals. 3a⁻1⁻a⁻)2a⁻1⁻:M, 3a⁻1°)3b⁻1⁻:L, 4b⁻)4b°:M, 4a⁻1°)4a⁻1⁻a⁻:L. Crural plates with distinct fulcral plates and supporting plates in young. Soudleyan and upper Longvillian.

Observations.—*Howellites* ranges through the upper part of the Soudleyan, and reap-

pears in the lowest zone of the upper Longvillian. The earliest forms have the fine, even ribbing that characterizes *Resserella*, s. s., and differ from that genus mainly in the greater convexity of the dorsal valve and in minor peculiarities of the interior. As we ascend the succession the ribbing loses its even character and becomes coarser, and this change is accompanied by the freer development of externals. This retrogressive transformation is remarkable in that it affects first the second, then the third, and finally the fourth sector. These changes are accompanied by a gradual divergence of the internal characters from the *Resserella* type.

The significant associates of *Howellites* are *Heterorthis*, *Sowerbyella sericea* and species of *Reuschella* of the *R. bilobata* group. They are found with typical *Howellites* both at the lower Soudleyan horizons and in the upper Longvillian. The later Soudleyan forms (*Howellites expectata*, etc.) are not associated with this fauna, and our generic determinations depend to a greater degree upon a synthesis of ribbing relations.

The affinities of the earlier species with *Resserella*, s. s., have already been noted: they are extremely close, and suggest that *Resserella*, s. s., is in most respects a good example of the common ancestral stock. From that stock it may be expected to differ in the characters that distinguish it from *Howellites*. These are: the feeble convexity of the dorsal valve in *Resserella*, s. s., the absence of a strong sinus traversing the adductor area in *Howellites* and the presence of distinct fulcral plates and supporting plates in the young stages of the latter subgenus. Both subgenera are distinguished from *Soudleyella* and *Onniella* by their high ventral valves, the presence of strong vascular sinuses in the ventral valve, and the relations 4a^{-1}°)4b^{-1} and 4a^{-1}°)4a^{-1}a^{-}. In Table VI I have set down the distinctive characters of the species I use as zonal indices.

RESSERELLA (HOWELLITES) STRIATA
Bancroft, n. sp.
Plate 26, figures 2–10; plate 27, figures 13–15; plate 28, figures 1–3

Valves c. 14 mm. wide, with few, fine concentric growth lines. Ribbing very fine and even. 3a^{-1}a^{-}, 3a^{-1}b^{-}, 3a^{-2}a^{-}, 3a^{-3}, [3b^{-1}a^{-}], 3b^{-1}, [3b^{-2}], [3b^{-1}°], [3c^{-1}], 3c^{-}, [3d^{-}], [3a°], [3a°1^{-}] terminal. 2b^{-1})2a°: H, 2c^{-})2a°:H, 3c^{-})3a°:H, 4c^{-})4c°:H. Interior of dorsal valve with strongly developed cardinalia; muscle area deeply impressed, with distinct peripheral ridge; anterior and posterior scars subequal; traces of internal ribbing usually extending to muscle area. Ventral muscle area large; adductor area wide, with inconspicuous vascular sinus or same absent. Interior of ventral valve usually with strong, repeatedly branching vascular sinuses.

TABLE VI

	2b^{-1})2a°	2c^{-})2a°	3a^{-1}a^{-})3a°	3c^{-})3a°	4b^{-})4b°
Howellites ultima	[M]	[M]	L	L	M
H. intermedia	L	L	H1-2	H1–2	H3
H. intermedia expectata	[L]	[L]	H	H	H
H. striata lineata	M3	H1	H	H1–2	H
H. striata	H	H2-3	H	H3	M3-H1

Variation.—The ribbing of this species is of a uniformly fine character, with derivatives of 3a^{-1}a^{-} in all mature individuals; the derivatives of 3b^{-1}, 3c^{-} and the rib 3d^{-} seem sometimes to be absent. The appearance of an early 3a° in some shells is interesting as it heralds the free development of externals in the derived species: it is usually very weak or absent in *R.* (*H.*) *striata*.

In the shells from the type band the cardinal process has a broad and strong shaft with a more or less conspicuous fissure extending throughout its length. The same type is found in shells from Meifod, though in some of these the shaft is relatively narrow, and the fissure obscure or absent.

In the ventral interior the vascular sinuses are normally very strongly developed and exhibit very distinct and complex branching in the anterior region of the shell; in other forms they are mainly restricted to the two principal trunks arising in the divaricator scars, and to their rather delicate branches.

Most of the shells from the type band are distorted by cleavage and vertical pressure; for the most part they are somewhat flattened and buckled, and the internal characters may be either exaggerated or obscured. A much better notion of the form is afforded by the shells from the Meifod District.

Type locality and horizon.—In the crags of Cerrig-y-Gath, south of Bala, in the large scarp by the south side of the wall, 880 feet (nearly) east of Tyn-y-cefn; c. 100 feet west of the wall junction 980 feet east of Tyn-y-cefn (Bancroft Coll: Bala 2a). The types are from a bed (1 ft. 6 in.–2 ft.) about 30 feet above the base of 2a (Bala 2a5). In the zone of *R.* (*Howellites*) *striata*.

Distribution and faunal associates.—The species occurs as a common fossil both in the Bala district and on the east side of Allt-yr-Gader, north of Meifod. In both districts the fossil is associated with *Sowerbyella sericea* and *Reuschella* sp., and, somewhat less intimately, with *Heterorthis retrorsistria*.[1] The species is not known outside the North Welsh Area.

Affinities.—This species is most intimately related to its successor in the sequence, *R. striata lineata*. It is distinguished from that variety by the proportions for the relations 1b⁻)1a°, 2b⁻1⁻)2a°, 2c⁻)2a° and 3c⁻)3a° all of which are somewhat higher in typical *R. striata*. The other species are in the main smaller, and diverge more widely from the *Resserella* type.

Resserella (Howellites) striata lineata Bancroft, n. var.
Plate 26, figures 11, 12; plate 28, figure 4

Shells finely and evenly ribbed. [3a⁻1⁻a⁻1⁻], [3a⁻1⁻b⁻], 3a⁻1⁻a⁻, [3a⁻2⁻a⁻], 3a⁻2⁻, [3a⁻3⁻], [3b⁻1⁻a⁻], [3b⁻2⁻], 3b⁻1⁻, [3c⁻1⁻], 3c⁻, [3d⁻], [3a°1⁻], 3a° terminal. 2b⁻1⁻)2a°: M3, 2c⁻)2a°: H1, 3a⁻1⁻a⁻)3a°:H.

The internal characters in this variety are similar to those in *R. striata*, but, perhaps, a little less strongly expressed. I have no specimens with strongly developed vascular sinuses.

Type locality and horizon.—Near the summit of the crags on Cerrig-y-Gath, at the wall junction 980 feet east of Tyn-y-cefn (Bancroft Coll.: Bala 2c). The cotypes are from the scree stream derived from this and neighboring localities (Bancroft Coll: Bala 2Bx). The horizon is in the zone of *H. striata lineata*, about 25 feet above Bala 2a5.

Associated fauna.—The associated fauna includes the large *Sowerbyella sericea* and *Rafinesquina* aff. *R. expansa*.

Affinities.—This form occupies an intermediate position between *R.* (*H.*) *striata* and *R.* (*H.*) *intermedia*. The affinities with the latter species are discussed in the description of that species.

Resserella (Howellites) intermedia Bancroft, n. sp.
Plate 27, figures 1–4; plate 28, figures 5, 6

Shells finely and evenly ribbed for the genus, or ribbing coarser and with more conspicuous externals. [3a⁻1⁻a⁻1⁻], 3a⁻1⁻a⁻, [3a⁻1⁻b⁻], [3a⁻2⁻a⁻], 3a⁻2⁻, [3a⁻3⁻], [3a⁻2°], [3a⁻1°], 3b⁻1⁻, [3c⁻1⁻], 3c⁻, [3d⁻], 3a° external. 2b⁻1⁻)2a°:L, 2c⁻)2a°:L, 3a⁻1⁻a⁻)3a°: H. Dorsal valve with robust crural plates and deeply impressed muscle scars, or the same less strongly developed; shaft of cardinal process sometimes long and broad and fissured throughout its length. In the ventral valve vascular sinuses usually obscure.

Variation.—The material for this species is rather badly distorted, and it is difficult to make clear statements concerning the variation. It is quite clear, however, that it exhibits a greater latitude than is found in the earlier species. The most finely ribbed shells are closely similar to *H. striata*, and have the same even surface characters; the more coarsely ribbed shells approach the latter species, and for the most part have more freely developed externals. The latter shells, as might be expected, exhibit more strongly ribbed interiors. As to the muscle

[1] These species are in the main segregated in particular beds which follow one another in the following order: 1, Main *Heterorthis retrorsistria* horizon. 2, Lower burst of *Sowerbyella sericea*. 3, Burst of *Howellites striata*. 4, Second *Heterorthis* band. This succession can be recognized in both districts.

scars and cardinalia, these may be closely similar to those in *H. striata*, or they may be much less strongly expressed. I have seen no ventral valves with strongly developed vascular sinuses.

Type locality and horizon.—In the section on Cerrig-y-Gath, south of Bala, c. 120 yards east of the ford 2200 feet south of Tyn-y-cefn. The types are from the fossil bed 4a3 as located in the following section:

4a1 The lowest exposure, 15 feet east of thorn tree. Gap in section, say 30–40 feet.
4a2 About 10 feet above base of large scarp, *H. intermedia.*
4a3 Fossil bed about 12 feet above 4a2 and in same scarp, *H. intermedia, Sowerbyella sericea.*

Associated fauna.—The species is associated with the large *Sowerbyella sericea* as at the lower horizons.

Affinities.—*H. intermedia* is distinguished from *H. striata lineata* by the lower percentages for the relations 2b⁻1⁻)2a° and 2c⁻)2a°, and from *H. ultima* by the high proportions of 3a⁻1⁻a⁻)3a° and 4b⁻)4b°. It seems to occupy an intermediate position between these forms.

Resserella (Howellites) intermedia expectata Bancroft, n. var.

Plate 27, figures 5–9; plate 28, figures 7, 8

Small shells with strongly convex dorsal valves, c. 12 mm. wide. Ribbing moderately fine. 3a⁻1⁻a⁻, 3a⁻2⁻, 3b⁻1⁻, 3c⁻3a° terminal. 3a⁻1⁻a⁻)3a°:H, 3c⁻)3a°:H, 4b⁻)4b°:H. Internal characters as in *H. intermedia* or with the dorsal muscle scars expanding anteriorly. Ventral adductor scar sometimes very narrow.

Variation.—The material for this variety was obtained from highly calcareous fossil bands, and for the most part has suffered little from vertical pressure. The material, therefore, affords a better idea of the general form of the subgenus than the shells from other Bala horizons. The strongly convex dorsal valve has the same form as the undistorted shells of *H. striata* from Meifod.

Among the abnormal variations of the cardinal process I may notice one in which the shaft is very fine owing to the approximation of the inner edges of the crural plates. The dorsal muscle area may have the form normal to the subgenus, or the sides may diverge towards the front as in *Onniella;* in the latter case the anterior scar may be somewhat larger than the posterior. The ventral interior sometimes shows a pair of narrow, sharply defined vascular trunks arising in the divaricator scars and branching near the periphery; more commonly the sinuses are coarser and more obscure. In some shells they appear to be absent.

Type locality and horizon.—In the gutter section on Cerrig-y-Gath, south of Bala, 3400 feet due south of Glyn Mawr. The types are from 4b2 as located in the following section commencing at the base of the main scarps:

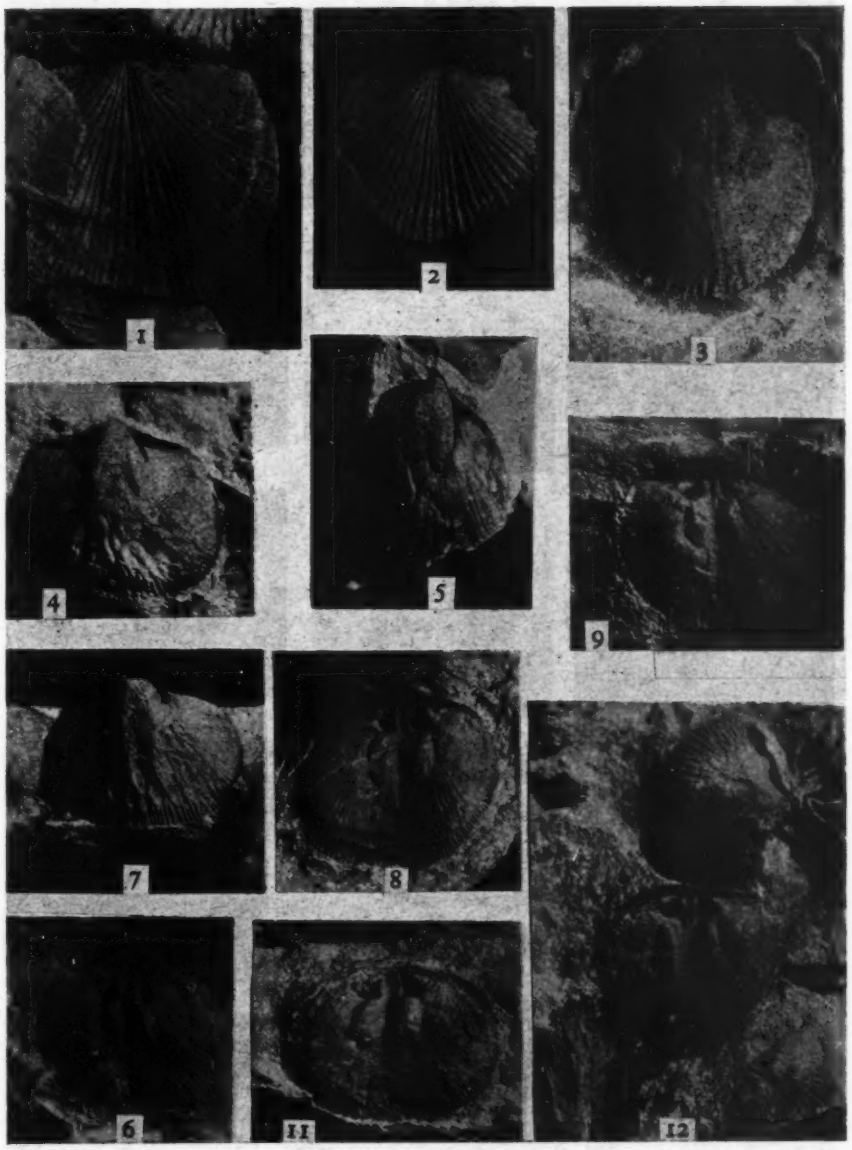
		Ft.	in.
4b	Fossil beds, about 7 feet above thorn.		
	Blue mudstone	2	6
4b1–4b2	Fossil beds with *H. intermedia expectata*		8
	Blue mudstone	11	2
4b4	Fossil bed with *H. intermedia expectata, Cliftonia, Reuschella*	4	0
	Blue mudstone	35	6
4b8	Fossil bed	1	3
	Blue mudstone	4	2
4b9	Fossil bed, *H.* cf. *H. ultima*		1
	Blue mudstone	1	7
4b10	Fossil bed		3
	Blue mudstone	10	10
	Gap	8	0
	Blue mudstone	20	7
4d1	Fossil bed		4
	Blue mudstone to top of section	20	3

Explanation of Plate 26

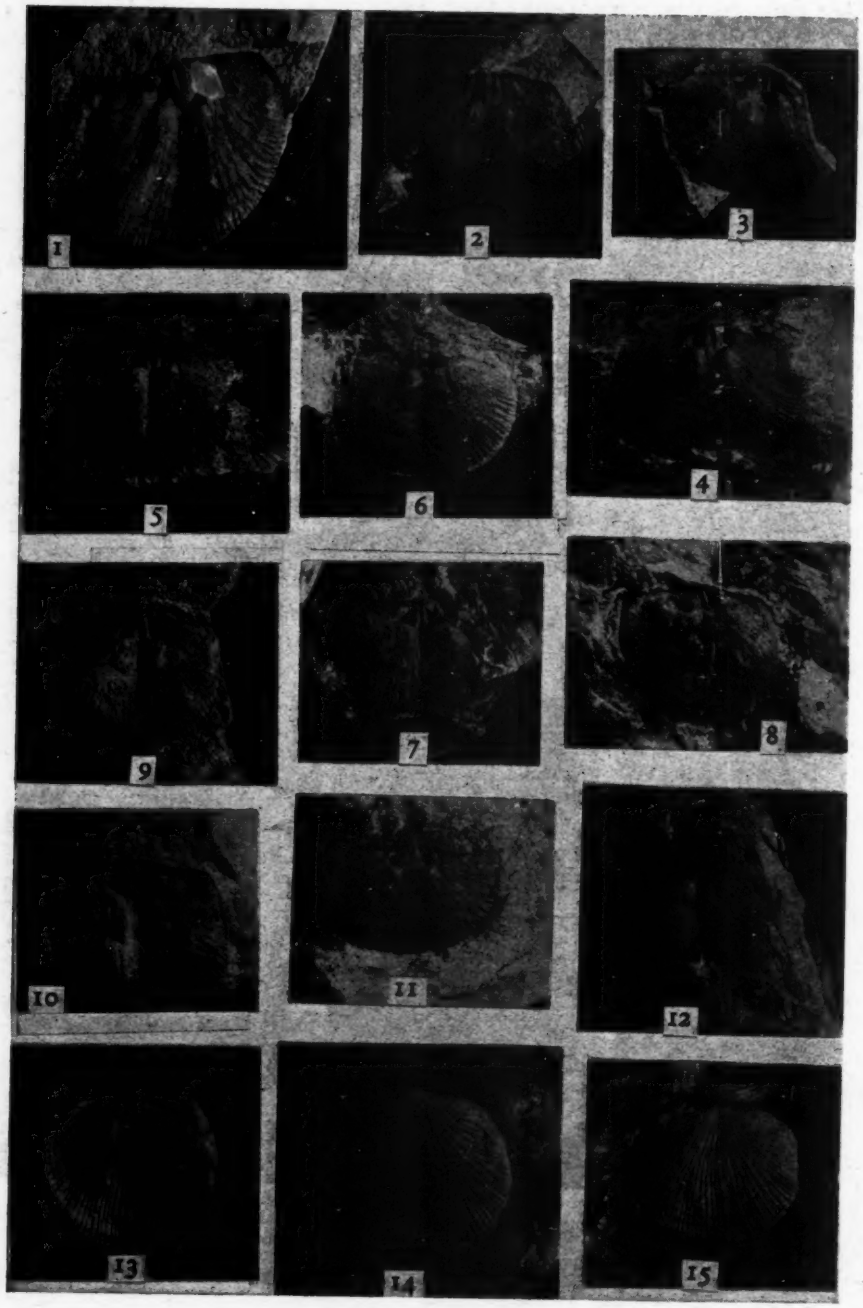
Figs. *1–3*—*Raymondella robusta* Bancroft, n. sp. *1, 2,* Casts from external moulds of dorsal valves, ×2; *3,* internal mould of ventral valve, ×2; all from the type band in the lane section at Woolston, Shropshire. (p. 201)

4–9—*Resserella* (*Howellites*) *striata* Bancroft, n. sp. *4, 5, 7,* Internal moulds of ventral valves, from the type locality on Cerrig-y-Gath, Bala, Merioneth (Bala 2a5), ×2; *6, 8,* internal moulds of dorsal valves from the type locality, ×2; *9,* internal mould of an undistorted dorsal valve from the *Howellites striata* zone of Allt-yr-Gader, Meifod, ×2. (p. 204)

11, 12—*Resserella* (*Howellites*) *striata lineata* Bancroft, n. var. Internal moulds from loose blocks derived from the type bed on Cerrig-y-Gath, Bala, Merioneth, ×2. (p. 205)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

The horizon is in the zone of *H. intermedia expectata* of the Soudleyan.

Associated fauna.—The associated fauna includes species of *Reuschella*, *Rafinesquina*, *Cliftonia*, *Camarotoechia*, *Tetradella* and *Bröggerolithus*. The large *Sowerbyella sericea* is not known from this horizon.

Affinities.—Except that it is somewhat smaller and more coarsely ribbed this variety has the same characters as *H. intermedia;* it may, therefore, be considered as of small value as an index fossil. I am convinced, however, that when sufficient material is available important distinctions will be discovered among the ribbing relations, and that these will justify the separation of the variety *expectata* as a new species.

Resserella (Howellites) ultima Bancroft, n. sp.

Plate 27, figures 10–12; plate 28, figures 9, 10

Shells c. 17 mm. wide, rather coarsely ribbed for the subgenus, with freely developed externals. 3a^{-}1^{-}a^{-}, 3a^{-}2^{-}, 3b^{-}1^{-}, 3c^{-}, [3b°], [3a°1^{-}], 3a°, [3a°1°] terminal. 3a^{-}1^{-}a^{-})3a°:L, 3c^{-})3a°:L, 4b^{-})4b°:M. Interior of dorsal valve with strongly developed cardinalia and deeply impressed muscle scars; the anterior and posterior scars separate and subequal. Internal ribbing more or less strongly defined in region external to muscle area. In ventral valve vascular sinuses feebly developed.

Material and variation.—This is another important but imperfectly known species. The available material is from highly cleaved mudstones, and includes far too few mature shells for a satisfactory study of variation. It would seem, however, that this is rather extensive and embraces character types not hitherto noticed in the subgenus.

Type locality and horizon.—In a small exposure 25 paces north of the gutter in the gutter section on Cerrig-y-Gath, and about 50 feet below the spring; c. 10 feet above 4d1 in the forementioned section. The material, which was collected from about 1 foot of rock, is from the zone of *H. ultima*, and not far below the *Reuschella horderleyensis* horizon.

Affinities.—In the Cerrig-y-Gath section *H. intermedia expectata* is succeeded by a series of forms with low proportions for 3a^{-}1^{-}a^{-})3a° and 3c^{-})3a°, and moderate proportions for 2b^{-}1^{-})2a° and 2c^{-})2a°. These forms include the forms from 4b9, *H. ultima* and forms from above the *ultima* horizon. Comparing *H. ultima* with *H. intermedia expectata* we note the lower proportions for 3a^{-}1^{-}a^{-})3a° and 3c^{-})3a° in the former; the proportions for 2b^{-}1^{-})2a° and 2c^{-})2a°, on the other hand, seem to be higher in that species, and suggest a return to the normal *Resserella* relations in that sector.

Genus Soudleyella Bancroft, n. genus

Genotype, *Soudleyella soudleyensis* Bancroft, n. sp.

Small, finely ribbed, transverse dalmanelloids with shallow dorsal and low ventral valves. Ribbing with freely developed externals. 2c^{-})2a°:L, 3a^{-}1^{-}a^{-})3a°:L, 4b^{-})4b°:M, 4a^{-}1°)4a^{-}1^{-}a^{-}:M–H, 4a^{-}1°)4b^{-}1^{-}:H. Crural plates conspicuoulsy small, *Resserella*-like, inner edges subparallel, socket lines narrowly divergent; *Wattsella* stage sometimes persisting in late growth stages. Dorsal muscle area small; anterior and posterior scars subequal. Interiors of both valves traversed by ribbing; internal ribbing normally traversing muscle areas. Vascular sinuses absent. Soudleyan.

Observations.—In its restricted sense this

Explanation of Plate 27

Figs. *1–4*—*Resserella* (*Howellites*) *intermedia* Bancroft, n. sp. Internal moulds of dorsal valves from the type band on Cerrig-y-Gath, Bala, Merioneth (Bala 4a3); all ×2. (p. 205)

5–9—*Resserella* (*Howellites*) *intermedia expectata* Bancroft, n. var. *5–7*, Internal moulds of dorsal valves from the type band on Cerrig-y-Gath south of Bala (Bala 4b2); *8*, internal mould from a few feet above the type band on Cerrig-y-Gath (Bala 4b4); all ×2; *9*, from Bala 4b2–4, ×2. (p. 206)

10–12—*Resserella* (*Howellites*) *ultima* Bancroft, n. sp. Internal moulds of dorsal valves from the type exposure on Cerrig-y-Gath, Bala; ×2. (p. 209)

13–15—*Resserella* (*Howellites*) *striata* Bancroft, n. sp. Casts from internal moulds of dorsal valves; *13, 14*, from the type locality (Bala 2a5); *15*, from the *Howellites striata* zone on Allt-yr-Gader, north of Meifod, Montgomeryshire; all ×2. (p. 204)

genus embraces a small group of species from the higher zones of the Soudleyan, where it is invariably associated with *Bröggerolithus soudleyensis* and the group of *Reuschella horderleyensis*. It is, therefore, an element of a special fauna, presenting a sharply defined facies and indisputably homogeneous. Somewhat less clearly related are the small forms from the Glenburrell beds of east Shropshire (*Soudleyella avelinei*, etc.) and the associates of *Salterolithus caractaci* at Welshpool. All these forms present the shallow valves, transverse form, and the characteristic ribbing relations of *Soudleyella*, s. s., and together with that group define the broad concept of the genus.

Variations from the normal type are confined mainly to the group of *S. avelinei* and late Harnagian shells. In both of these groups the inner edges of the crural plates are normally divergent, and it is only in the more strongly developed interiors that the characteristic *Soudleyella* type is discovered. A pair of fine, divergent vascular trunks is not infrequently developed in *S. avelinei*. The broader concept of the genus must be defined in accordance with these observations, and its range extended to embrace the Soudleyan and Harnagian.

The ribbing relations which I have described as the *Onniella* type are found in their entirety only in *Soudleyella*, s. s., *Onniella* and normal forms of *Wattsella*, and serve to distinguish *Soudleyella* from other genera. From *Resserella*, which has the same kind of crural plates, *Soudleyella* is also distinguished by the small size of those structures, by the small size and generalized character of its muscle scars, by the absence of coarse and complex vascular sinuses, by its shallow ventral valve, and by the small size and prevailingly transverse form of the shells.

The relation of *Soudleyella* to *Dalmanella* of Schuchert and Cooper is somewhat obscure. *D. rogata* Hall and Clarke is contemporaneous with the lower Soudleyan *S. avelinei*, a form which it resembles both in its ribbing and internal characters. It is not impossible, therefore, that *D. rogata* and its allies and *Soudleyella* are referable to the same genus, in which case *Soudleyella*, s. s., may be regarded as a subgenus of *Dalmanella*. The objection to referring our *Soudleyella* to *Dalmanella* arises from the fact that Schuchert's interpretation of that genus has already been challenged (Öpic, 1933), and the name is likely to be used in various senses by different writers as long as it is retained in the classification. In the meantime I wish to attach a more precise significance to my generic groupings.

SOUDLEYELLA SOUDLEYENSIS
Bancroft, n. sp.
Plate 28, figures 11–17

Shell small, transverse, c. 10 mm. wide; hinge wide. Dorsal valve very shallow, with feebly defined sinus. Ribbing fine. 3a^{-1}-a^{-}, 3a^{-2}-, [3a^{-1}°], 3b^{-1}-, 3c^{-}, 3a° terminal. 2a^{-1}-)2a°:M, 2b^{-1}-)2a°:L, 3a^{-1}°)3a^{-1}-a^{-}:L-M, 3a^{-1}°)3b^{-1}-:L3-M, 4a^{-1}°)4a^{-1}-a^{-}:H, 4c^{-})4c°:L. Growth lines obscure or absent. Crural plates small, *Resserella*-like. Cardinal process variable; shaft usually slender and without fissure. Dorsal muscle area small; anterior and posterior scars subequal, narrow, traversed by ribbing of interior; margins defined by special ridges and internal ribs. Dental plates strong, widely divergent, united at front with lateral boundary ridges of muscle area. Dental plates and boundary ridges forming a pair of characteristically curved grooves in internal moulds. Ventral muscle area large, feebly differentiated; anterior margin often indefinite. Vascular sinuses absent. Interiors of both valves traversed by internal ribbing.

Variations.—The variations include a rather long form for the genus, a variety of types of notothyral platform, and variations in the ventral muscle area. The notothyral platform is usually very narrow owing to the close approximation of the inner edges of the crural plates, but in some individuals it is quite wide and flat. In either case the cardinal process is usually feebly developed, and the shaft slender and of variable length. Abnormally the ventral muscle area is clearly subdivided into a pair of large divaricator scars and a narrow adductor area. The other internal characters such as the crural plates and dorsal muscle area exhibit a notable consistency in this species.

Type locality and horizon.—In the old quarry in Longville Plantation south of Horderley, immediately west of the 'P' in 'Plantation' on the 6-inch Ordnance Survey

map; in the fossil band W18/17 as located in the following section:

			Ft.	in.
W18.	1	Sandstones, finely colour-banded in green and purple, with some dark grey thin beds; at top shale with bands of green sandstone. Several feet.		
	2	Dark-grey and greenish micaceous shales.....	1	1
	3	Light-green laminated sandstone.....		7½
	4	Shale.....		6
	5	Massive green- and purple-banded sandstone with flaggy sandstone at top..	4	0
	6	Soft black shales and flaggy beds.....	3	3
	7	Massive green-and-purple-banded sandstone, a thin shale band and a fine green sandstone.....	10	3
	8	Glossy black shales and thin green sandstones...	2	3
	9	Massive green-and-purple-banded sandstone.....	2	7
	10	Thin beds of sandstone and glossy black shales.....	3	6
	11	Massive green-and-purple-banded sandstone.....	4	0
	12	Shale, flaggy above.....		7½
	13	Purple sandstone.....	1	7
	14	Light-grey shale.....		2½
	15	Brownish purple sandstone		11½
	16	Light-grey shale.....	2	2½
	17	Sandstone, green-and-purple-banded, blackish purple towards the top. Thin fossil beds, *Basilicus, Bröggerolithus, Rafinesquina* aff. *R. expansa, Sowerbyella, Soudleyella*....	11	0
	18	Thin flags and shales to top of quarry.		

The horizon is in the main Green and Purple sandstone in the zone of *Reuschella horderleyensis* and *Bröggerolithus soudleyensis*.

Distribution and associated fauna.—Varieties of this species are common in the lower Horderley sandstone of East Shropshire and in the shelly mudstones about 100 feet below the *Dinorthis multiplicata* zone at Meifod. At these localities the species is associated with *Bröggerolithus soudleyensis*, the group of *Reuschella horderleyensis*, and *Dinorthis* sp. The species is restricted to the *Reuschella horderleyensis* zone.

Affinities.—I have referred to the forms from the lower Horderley sandstone as varieties of *S. soudleyensis*, but have not taken note of their characters in the description of the species; this is because I believe that these forms, when properly understood, will be separated as distinct species. The lower Horderley shells differ in having the external ribs less freely developed, and in the presence of distinct socket plates and supports in some of the shells. The Meifod shells are somewhat larger than the other forms, but are otherwise typical. They are about 12 mm. wide. (See Table VII.)

Genus ONNIELLA Bancroft

Onniella BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 55.

Genotype, *O. bröggeri* Bancroft.

Shells transversely subrectangular to moderately long. Hinge wide, or becoming narrower in late growth stages. Dorsal valve variable; ventral valve low, with small beak. Ribbing with freely developed esternals. 2b^{-1})2a°:L–M, 2c^{-})2a°:L–M, 3a^{-1}-a^{-})3a°:L, 3c^{-})3a°:L, 4b^{-})4b°:L, 4c^{-})4c°:L, 4a^{-1}°)4a^{-1}-a^{-}:M-H, 4a^{-1}°)4b^{-1}-:L. Cardinal process with large fissured myophore and strong shaft, or shaft resorbed in myophore. Crural plates *Resserella*-like; socket lines widely divergent. Dorsal muscle area with large anterior scars and small posterior scars, or scars subequal at maturity. Ventral muscle area small and shallow, or becoming large and flattened in gerontic shells, feebly differentiated; anterior margin obscure or indefinite. Vascular sinuses absent or feebly developed. Marshbrookian to Pusgillian.

Observations.—Young shells present a distinctive ensemble of characters which sometimes persists to maturity. The main features of this ensemble are: 1, The transverse shell with wide hinge; 2, the low ventral valve with small beak; 3, ribbing with *Onniella* facies; 4, *Resserella*-like crural plates; 5, the large anterior scars and small posterior scars in the dorsal valve; 6, the small feebly developed ventral muscle area; 7, the absence of vascular sinuses.

Apart from a relative shortening of the hinge, the entire assemblage of these characters persists in the group of *Onniella bröggeri*. The mature *O. reuschi* and its allies have the same transverse shell often associated with a rather long hinge, and the

same type is not uncommon in all the Actonian assemblages. In some species, however, the prevailing form is only slightly transverse, the margin rounded, and the hinge rather short.

The cardinal process is always a rather variable structure. In its simplest form it consists of a fissured myophore and slender shaft; in its most massive development the myophore and shaft are fused into a single deeply fissured, ovoid body nearly filling the entire space between the crural plates. Intermediate between these forms is the type with a distinct myophore and a broad fissured shaft, and that in which the shaft persists as a fine ridge between the greatly extended myophore plates. All these variations may be associated in the same assemblage.

The crural plates may be solid and *Resserella*-like, or they may be imperfectly resolved into fulcral plates and supporting plates by a variably developed crural pit. The most characteristic species have the massive type of crural plate strongly developed, and this is always the dominant type in all assemblages.

In characteristic species the dorsal muscle area has strong boundary ridges and partition ridges, and is subdivided into a pair of conspicuously large anterior scars, and a pair of small posterior scars. The posterior scars are subquadrate, and the anterior scar

TABLE VII

	2a⁻1⁻)2b⁻	2b⁻)2a°	2a⁻1⁻)2a°	3a⁻1°)3a⁻1⁻a⁻	3a⁻1°)3b⁻1⁻	4b⁻)4b°	4a⁻1°)4a⁻1⁻a⁻
Soudleyella soudleyensis, s. s.	[M]		[M]	M	M		H
S. soudleyensis, var., Meifod	L	[H]	[M]	[L]	L[3]		M
S. soudleyensis, var., lower Horderley	L	H3	H3	L	L3	M1-2	H2
Soudleyella, s. l., Chatwall	M	H1–2		L1–2	M		M2–3
Soudleyella (s. l.) *avelinei*		H	H	[L]	L1–2	M2	[H]

EXPLANATION OF PLATE 28

FIGS. 1–3—*Resserella* (*Howellites*) *striata* Bancroft, n. sp. Casts from external moulds from the type bed on Cerrig-y-Gath, Bala (Bala 2a5); all ×2. (p. 204)

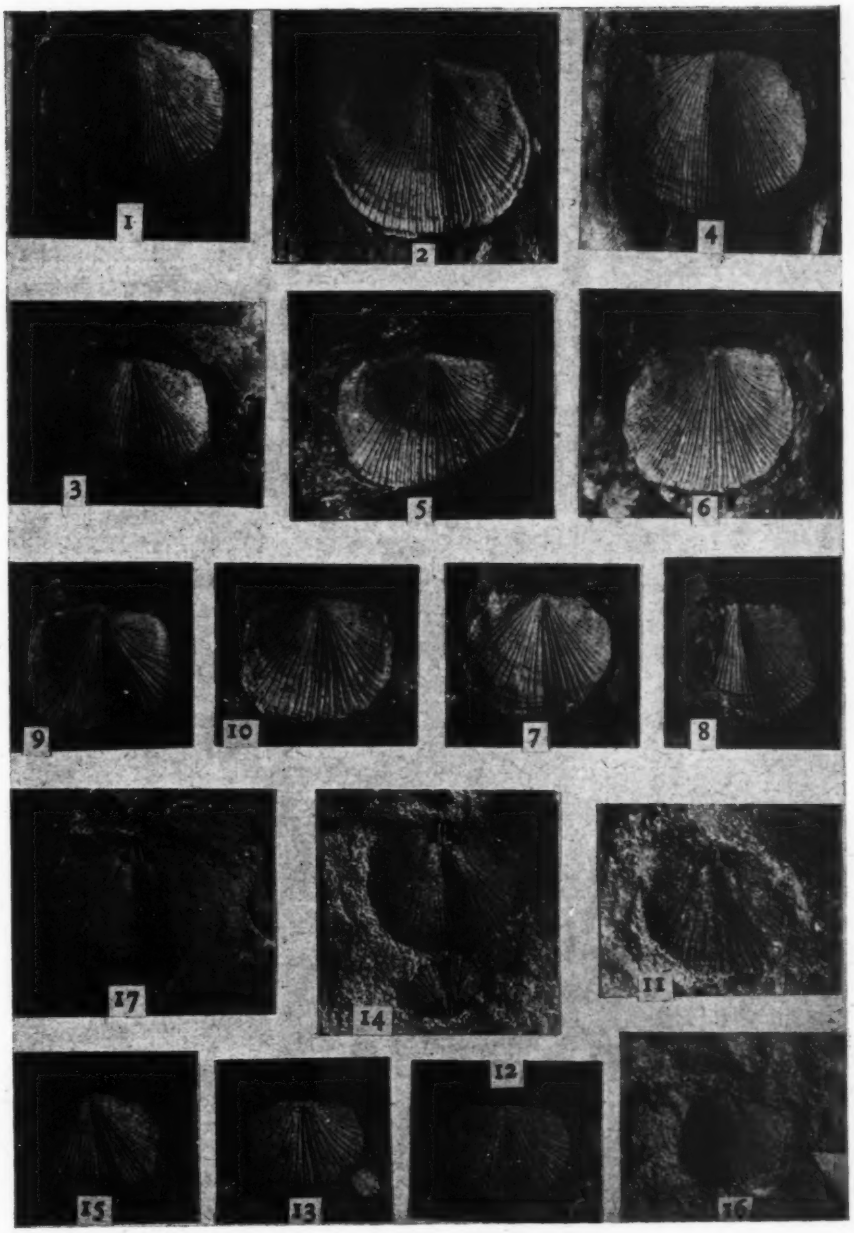
4—*Resserella* (*Howellites*) *striata lineata* Bancroft, n. var. Cast from external mould of dorsal valve on block derived from type locality; ×2. (p. 205)

5, 6—*Resserella* (*Howellites*) *intermedia* Bancroft, n. sp. Casts from external moulds of dorsal valves; both from the type band (Bala 4a3); ×2. (p. 205)

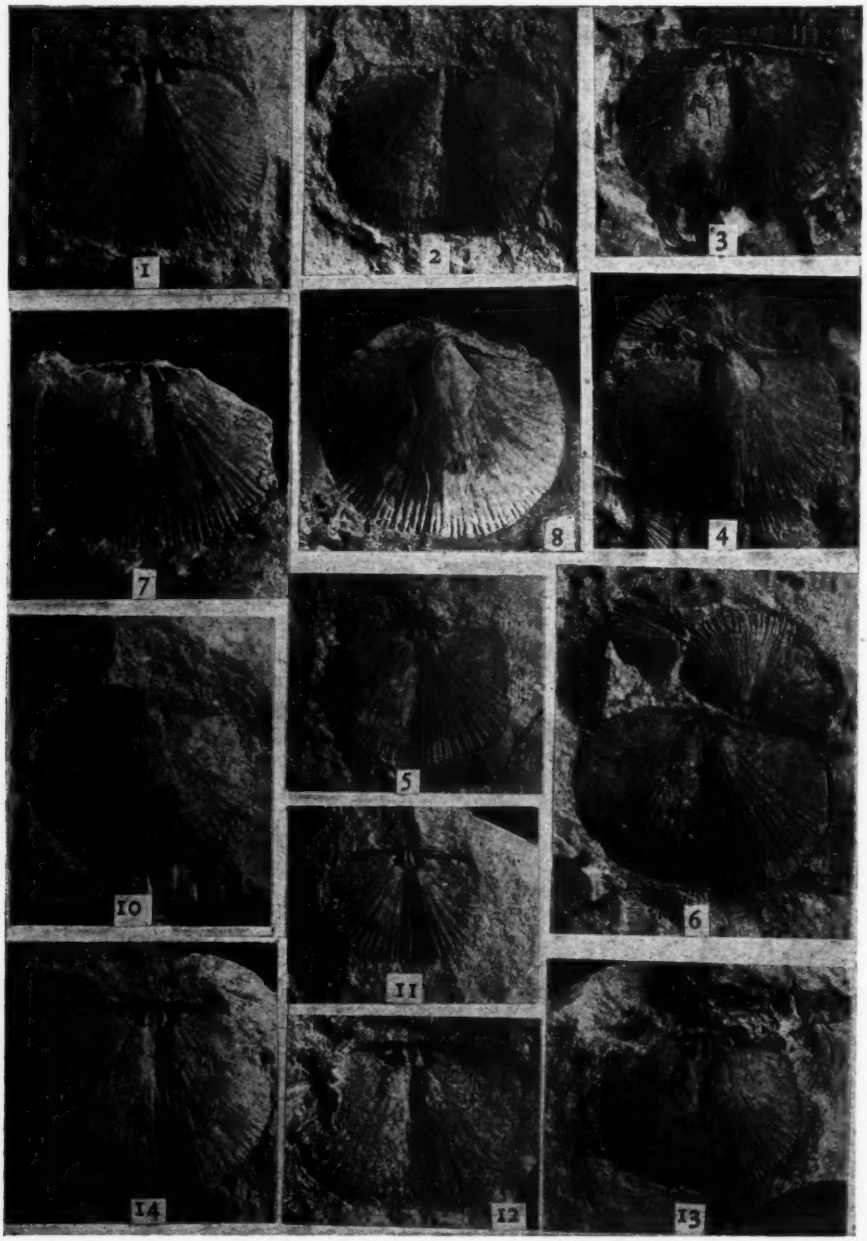
7, 8—*Resserella* (*Howellites*) *intermedia expectata* Bancroft, n. var. Casts from external moulds of dorsal valves. *7*, from the type band (Bala 4b2); *8*, from a few feet above the type band (Bala 4b4); both ×2. (p. 206)

9, 10—*Resserella* (*Howellites*) *ultima* Bancroft, n. sp. Casts from external moulds of dorsal valves; from the type exposure on Cerrig-y-Gath, south of Bala, Merioneth; both ×2. (p. 209)

11–17—*Soudleyella soudleyensis* Bancroft, n. sp. *11–13*, From the type band (W18/17) in Longville Plantation, Horderley, Shropshire; ×2; *14–16*, from the lower Horderley sandstone of the railway section at Horderley; *17*, from the *Reuschella horderleyensis* zone of Gallt-yr-Ancr, Meifod, Montgomeryshire, ×2. Fig. *14* shows an immature dorsal interior with *Wattsella*-like crural plates. (p. 210)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

subtrigonal when the lateral angulation is in front of the partition; otherwise the anterior scars are quadrangular, with long, convergent anterolateral margins. Abnormally the scars are subequal or inseparate. The typical form is predominant in all known post-Marshbrookian assemblages.

The ventral muscle area is nearly always feebly developed and weakly differentiated, and normally it is rather small. When it exceeds the normal limits it may attain to a considerable size as in certain gerontic individuals. In these shells the extension of the area in front of the dental plates is apparent only from the weak lateral boundary ridges. In many shells the area is defined only between the divergent dental plates, so that the form is indeterminate.

Vascular sinuses are usually absent or restricted to a pair of very fine and rather obscure trunks arising in the divaricator scars; abnormally the principal trunks are quite broad but very shallow, and split up into a number of branches in the anterior region.

From the foregoing it will appear that *Onniella* is essentially a large *Soudleyella*-like genus with a small ventral umbo, a large and complex cardinal process, widely divergent socket lines, and a large anterior and small posterior scars in the dorsal valve. The internal characters in the dorsal valve are sometimes closely similar to those in *Resserella*, s. s., but in that genus the scars in the dorsal valve are normally subequal, and the cardinal process never attains to the extravagant development which is sometimes found in *Onniella*. Besides these differences we may note the different form of the ventral valves in these genera, the strongly developed internal characters in the ventral valve of *Resserella*, and the progressive type of ribbing in that genus. From a morphological viewpoint much closer affinity exists between *Onniella* and the later species of *Howellites;* this resemblance evidently results from convergence.

The study of the rib system in *Onniella* has shown that it embraces several distinct phyla in the late Marshbrookian, Actonian and Onnian. Each of these phyla represents a progressive trend, and may be derived, at least hypothetically, in *O. reuschi*. The main groups are:

1, The group of *Onniella grandis* including *O. reuschi*, *O. grandis*, *O. aspasia*, *O. depressa* and *O. inconstans*. The shells, which often attain to a large size, are typically transversely subrectangular, with fine or rather fine ribbing.

2, The group of *O. bröggeri* characterized by the small shell and relatively coarse ribbing. In this group the difference between the size of the anterior and posterior scars in the dorsal valve is very conspicuous. The group includes *O. bröggeri* and *O. sinuata*.

ONNIELLA REUSCHI Bancroft

Plate 29, figures 1–6; plate 30, figures 1–3

Onniella reuschi BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 57, pl. 11, figs. 10–13.

Finely ribbed, subrectangular shells, 13–17 mm. wide. Hinge wide. Dorsal valve shallow, with shallow, rounded sinus. [3a^{-1}-a^{-1}-], 3a^{-1}-a^{-}, [3a^{-1}-b^{-}], [3a^{-2}-a^{-}], 3a^{-2}-, [3a^{-3}-], 3a^{-1}°, [3b^{-1}-a^{-}], 3b^{-1}-, [3b^{-2}-],

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EXPLANATION OF PLATE 29

FIGS. *1–6—Onniella reuschi* Bancroft. *1, 2,* Internal moulds of dorsal valves from the *Kjerulfina polycyma* zone of the Onny River section, Southeast Shropshire, ×2; *3–6,* internal moulds from the type locality (L12), Woolston, Shropshire, ×2. (p. 215)

7–8—Onniella grandis Bancroft, n. sp. *7,* Internal mould of dorsal valve, ×2; *8,* internal mould of ventral valve, ×2; both from the type exposure in the stream section west of Hatton, Southeast Shropshire (Hatton 15). (p. 217)

10–12—Onniella aspasia Bancroft, n. sp. *10,* Internal mould of ventral valve, ×2; *11, 12,* internal moulds of dorsal valves, ×2; all from the type locality in Dandy Hollow, west of Wistanstow, Southeast Shropshire. (p. 217)

13—Onniella sp. Internal mould of dorsal valve from the stream section in Dandy Hollow, west of Wistanstow, Shropshire (Bancroft Coll: Q7), c. 30 ft. below the *O. aspasia* horizon; ×2. (p. 211)

14—Onniella grandis Bancroft, n. sp. Internal mould of dorsal valve from the type locality at Hatton; ×2. (p. 217)

[3b⁻1°], [3c⁻1⁻], 3c⁻, [3d⁻], 3b°, 3a°1⁻, 3a°, [3a°1°] terminal. 1b⁻)1a°:M2, 2a⁻1⁻)2b⁻:L2, 2c⁻)2a°:L2, 3a⁻1⁻a⁻)2b⁻:L1–2, 3a⁻1⁻a⁻)2a°:M3, 3c⁻)3a°:L1, 3a⁻1°)3a⁻1⁻a⁻:L3, 3a⁻1°)3b⁻1⁻:M2, 3b⁻1⁻)3c⁻:M2. Growth lines strong and shelving to faint. Spaces between ribs with fine, closely set concentric striae. Cardinal process large and complex, filling entire space between crural plates, or small and with distinct myophore and shaft. Crural plates small and solid or with more or less distinct fulcral plates and supports. Dorsal muscle area small, obscure or with very shallow scars more or less perfectly defined by fine boundary ridges; anterior and posterior scars subequal or inseparate. Dental plates short and slender. Ventral muscle area small, shallow and feebly differentiated, bounded by fine lateral ridges; anterior margin indefinite or obscure. Vascular sinuses absent. Interiors of both valves more or less distinctly ribbed.

Variation.—Besides the more characteristic forms this species includes a series of relatively long shells usually with rounded anterior margins. The ribbing associated with the two types appears to be identical.

The cardinal process and crural plates exhibit the full range of variation described in the account of the genus, but the latter are always very small, and strongly developed supporting plates are of rare occurrence. Specimens with large and deeply impressed muscle areas are quite unknown in this species.

Type locality and horizon.—At the junction of the lanes from Whittingslow and the Corner to Woolston, at Woolston in the Horderley district. The type specimens are from the small exposure in the angle between the roads (Bancroft Coll: L12). The cotypes are from the lane section south of the old quarry in Marsh Wood, north of Horderley. Both horizons are in the zone of *Kjerulfina polycyma*.

TABLE VIII

	1b⁻)1a°	2a⁻1⁻)2b⁻	2b⁻)2a°	2b⁻1⁻)2a°	2c⁻)2a°	3a⁻1⁻a⁻)2b⁻	3a⁻1⁻a⁻)2a°	3a⁻1⁻a⁻)3a°	3c⁻)3a°	3a⁻1⁻a⁻)3a⁻2⁻	3b⁻1⁻)3c⁻	3a⁻1°)3a⁻1⁻a⁻	3a⁻1°)3b⁻1⁻	4a⁻1⁻a⁻)4a⁻2⁻
O. bröggeri		H1	H3	L–M	L–M	H2	H3	L2	L2	H2–3	M	L1	L2	H3
O. sinuata	80.6	73	97	52	43	40	95.3	26	6.1	89	64	0	20	95
O. inconstans	93	85	100	(75)	(60)	57	98	56	28	91	78	2	7	96
O. depressa	86.1	55	96	44	46	26	95	37	16.6	88	56	4	18	95
O. aspasia	90	40.7	94	48	53	29	96	31	16.0	85	52	9	15	65
O. grandis	63	27.7	87	22	25	22	77	17	8.6	76	55	32	40	63
O. reuschi	55.7	21.3	85	17	16.6	11	63	6	3.8	75	53	31.5	52.5	74

Associated fauna and distribution.—The associated fauna includes the following: *Chasmops macroura*, *Heterorthis alternata* var., *Kjerulfina polycyma*, *Hedstroemina fragilis*, *Tentaculites* aff. *T. obliquus*. The species is known only in the zone of *Kjerulfina polycyma* of East Shropshire and Westmorland.

Affinities.—*O. reuschi* is the initial member of several series presenting multiple progressive trends. Of these series that embracing *O. reuschi*, *O. grandis*, *O. aspasia*, and *O. inconstans* may be regarded as a line of descent, but it is most probable that either *O. aspasia* or *O. inconstans* is slightly divergent from the direct line. A similar line relates the series, *O. reuschi*, *O. grandis*, *O. depressa* and *O. inconstans*, *O. depressa* being slightly divergent. In each of these lines about 12 out of 15 character relations exhibit continuous, unidirectional trends.

The statistical data are shown in Table VIII, where the above species and *O. brŏggeri* are arranged in stratigraphical order. The stratigraphical position of *O. sinuata* is between *O. depressa* and *O. inconstans*.

ONNIELLA GRANDIS Bancroft, n. sp.
Plate 29, figures 7, 8, 14; plate 30, figures 4–6

Large, finely ribbed, subrectangular shells 15–17.5 mm. wide. Hinge wide. Dorsal valve shallow, with shallow sinus. [3a^{-}1-a^{-}1^{-}], 3a^{-}1-a^{-}, [3a^{-}1-b^{-}], [3a^{-}2-a^{-}], 3a^{-}2^{-}, [3a^{-}3^{-}], 3a^{-}1°, [3b^{-}1-a^{-}], 3b^{-}2^{-}], 3b^{-}1^{-}, [3b^{-}1°], [3b^{-}1°a°], 3c^{-}1^{-}, 3c^{-}, [3c^{-}1°], [3d^{-}], [3b°], [3a°1^{-}], 3a°, [3a°1°] terminal. 1b^{-})1a°: M3, 2a^{-}1^{-})2b^{-}:L3, 2c^{-})2a°:L3, 3a^{-}1-a^{-}) 2b^{-}:L2–3, 3a^{-}1-a^{-})2a°:H1–2, 3c^{-})3a°:L1, 3a^{-}1°)3a^{-}1-a^{-}:L3, 3a^{-}1°)3b^{-}1^{-}:M1, 3b^{-}1^{-}) 3c^{-}:M2–3. Growth lines strong and shelving to faint. Crural plates small to moderately robust, with or without small crural pits. Dorsal muscle area normally well-developed, more rarely small, and with ill-defined boundary ridges and partition ridges; anterior scars normally somewhat larger and wider than the posterior scars. Dental plates consisting of a pair of slender, divergent laminæ. Ventral muscle area large but relatively shallow, sharply defined by peripheral ridge. Lobes of divaricator scars produced anteriorly in a pair of simple or branching vascular sinuses, or vascular sinuses absent. Internal ribbing usually weakly developed in inner regions of shell, only rarely invading muscle areas; sometimes restricted to peripheral zone.

Variation.—This is a rather consistently transverse species, the narrower types of shell being relatively rare, and never attaining to the proportionate length sometimes found in *O. reuschi*. The ribbing, on the other hand, includes types as fine as in the normal *O. reuschi*, and others nearly as coarse as the most coarsely ribbed shells of *O. aspasia*. These extreme types, however, are quite rare, and in this respect the bulk of the material is intermediate between the norms of the ancestral and derived species. The following are characteristic measurements of three individuals: width, 17.5, 15.0, and 16.0 mm.; length of dorsal valve, 12.25, 12.0, and 11.5 mm.

Abnormal internal variations include small and feebly defined muscle scars and small crural plates, sharply defined internal ribbing which invades the muscle scars, and the absence of vascular sinuses in the ventral valve.

Vascular sinuses are present in rather more than half of my specimens, and usually consist of a pair of delicate divergent trunks. In some specimens these die out between the muscle area and the front of the shell; in others they bifurcate and may form complex systems. The strongly developed, irregular type of sinus system characteristic of *Resserella* is never found in this species.

Type locality and horizon.—In the stream section on the north side of the road west of Hatton, northeast of Horderley, c. 700 feet nearly due west of Hatton village, 30–35 feet northwest of junction of hedge and stream at north end of sheep dip (Bancroft Coll: Hatton 15). The locality is in a low exposure of bluish mudstones by a fine ash tree, in the north bank of the stream. The horizon is in the zone of *Onniella grandis*, a few feet above the base of the Acton Scott beds.

Associated fauna.—I have found the folfowing fossils at the type locality: *Hedstroemina*, *Modiolopsis*, *Colpomya*, *Primitia*, *Tentaculites* (with closely set rings).

Affinities.—As evinced by the statistical data this species lies on the line of descent leading from *O. reuschi* to *O. inconstans*, and occupies a position between the former and *O. aspasia*. The general characters support this conclusion.

The species is most readily distinguished from *O. reuschi* by the following characters: 1, the greater size of *O. grandis;* 2, the coarser character of the ribbing in *O. grandis;* 3, the larger, deeper and more strongly defined muscle scars in *O. grandis;* and 4, the frequent occurrence of vascular trunks in the ventral valve of *O. grandis*.

ONNIELLA ASPASIA Bancroft, n. sp.
Plate 29, figures 10–12; plate 30, figures 7–9

Shells large, transversely subrectangular to subquadrate, 15–17 mm wide. Hinge wide. Ribbing moderately fine to rather coarse. 3a^{-}1-a^{-}, [3a^{-}1-b^{-}], [3a^{-}2-a^{-}], 3a^{-}2^{-}, [3a^{-}3^{-}], [3a^{-}1°], [3b^{-}1-a^{-}], 3b^{-}1^{-}, [3b^{-}2^{-}], [3b^{-}1°], [3c^{-}], [3a°1-a^{-}], [3a°1^{-}], [3a°2^{-}], 3a°, [3a°1°], [3a°2°] terminal. 1b^{-})1a°:H3, 2a^{-}1^{-})2b^{-}:M1, 2c^{-})2a°:M2, 3a^{-}1-a^{-})2b^{-}:

L3, 3a^{-1}-a^{-})2a°:H3, 3c^{-})3a°:L2, 3a^{-1}°) 3a^{-1}-a^{-}:L1, 3a^{-1}°)3b^{-1}-:L2, 3b^{-1}-)3c^{-}: M2. Crural plates small to moderately robust with or without crural pits. Dorsal muscle area usually small and shallow, feebly defined and traversed by internal ribbing. Ventral muscle area moderately large to large, usually defined by strong boundary ridges at the sides; anterior margin often obscure. Vascular trunks absent. Traces of internal ribbing extending to muscle areas or restricted to a broad peripheral zone.

Variation.—The following are measurements of transverse and subquadrate specimens: 17.0 mm. (width) by 12.0 mm. (length of dorsal valve); 16.5 mm. by 12.0 mm.; 15.5 mm. by 12.5 mm.

Both in this and the preceding species some of the derivatives which are placed in parentheses in the diagnoses are usually present. 3a°1-a^{-}, 3a°2^{-} and 3a°2°, on the other hand, occur only in abnormal specimens in which 3a° arises close to the umbo.

Type locality and horizon.—In the quarry in Dandy Hollow, half a mile west-northwest of Wistanstow, East Shropshire, a few feet northeast of top of 'a' in 'Batch Gutter' on the 6-inch Ordnance Survey map. The type specimens are from the lowest beds in the quarry and a small exposure a few paces to the south (Bancroft Coll: Q8a). The horizon is in the calcareous mudstone of the zone of *O. aspasia*, about 50 feet above the base of the Acton Scott beds.

Associated fauna.—*Chasmops macroura. Hedstroemina, Chonetoidea, Kjaerina* sp., *Oxydiscus.*

Affinities.—*O. aspasia* is the third species in the line leading from *O. reuschi* to *O. inconstans.* Statistically it is distinguished from *O. grandis* by the relatively late appearance of the externals and corresponding changes in the percentage data. It is further distinguished from *O. grandis* by: 1, the absence of very finely ribbed types like the mode in *O. reuschi;* 2, the smaller, less strongly defined dorsal muscle area; 3, the more delicate character of the crural plates, which frequently exhibit crural pits; and 4, the absence of vascular trunks in the ventral valve.

Onniella depressa Bancroft, n. sp.
Plate 30, figures 10–13

Moderately large, rather finely ribbed shells with rounded contour; valves rather long for genus. Hinge moderately wide. [3a^{-1}-a^{-1}-], 3a^{-1}-a^{-}, [3a^{-1}-b^{-}], 3a^{-2}-, [3a^{-} 3^{-}], 3a^{-1}°, [3b^{-1}-a^{-}], 3b^{-1}-, [3b^{-2}-], 3c^{-}, [3d^{-}], [3a°1^{-}], 3a°, [3a°1°[terminal. 1b^{-})1a°: H2, 2a^{-1}-)2b^{-}:M2–3, 2c^{-})2a°:M2, 3a^{-1}-a^{-})2b^{-}:L3, 3c^{-})3a°:L2.

Material.—The shells occur in the form of conjoined valves in a calcareous mudstone. Both valves are much flattened and buckled by load pressures, which in the case of the dorsal valve have almost invariably reversed the convexity. The internal characters are unknown.

Explanation of Plate 30

Figs. *1–3—Onniella reuschi* Bancroft. *1*, Cast from external mould of ventral valve from the type locality at Woolston, Shropshire, ×2; *2*, cast from external mould of dorsal valve from the type locality, ×2; *3*, cast from external mould of dorsal valve from the *Kjerulfina polycyma* zone of the Onny River section (P8), ×2. (p. 215)

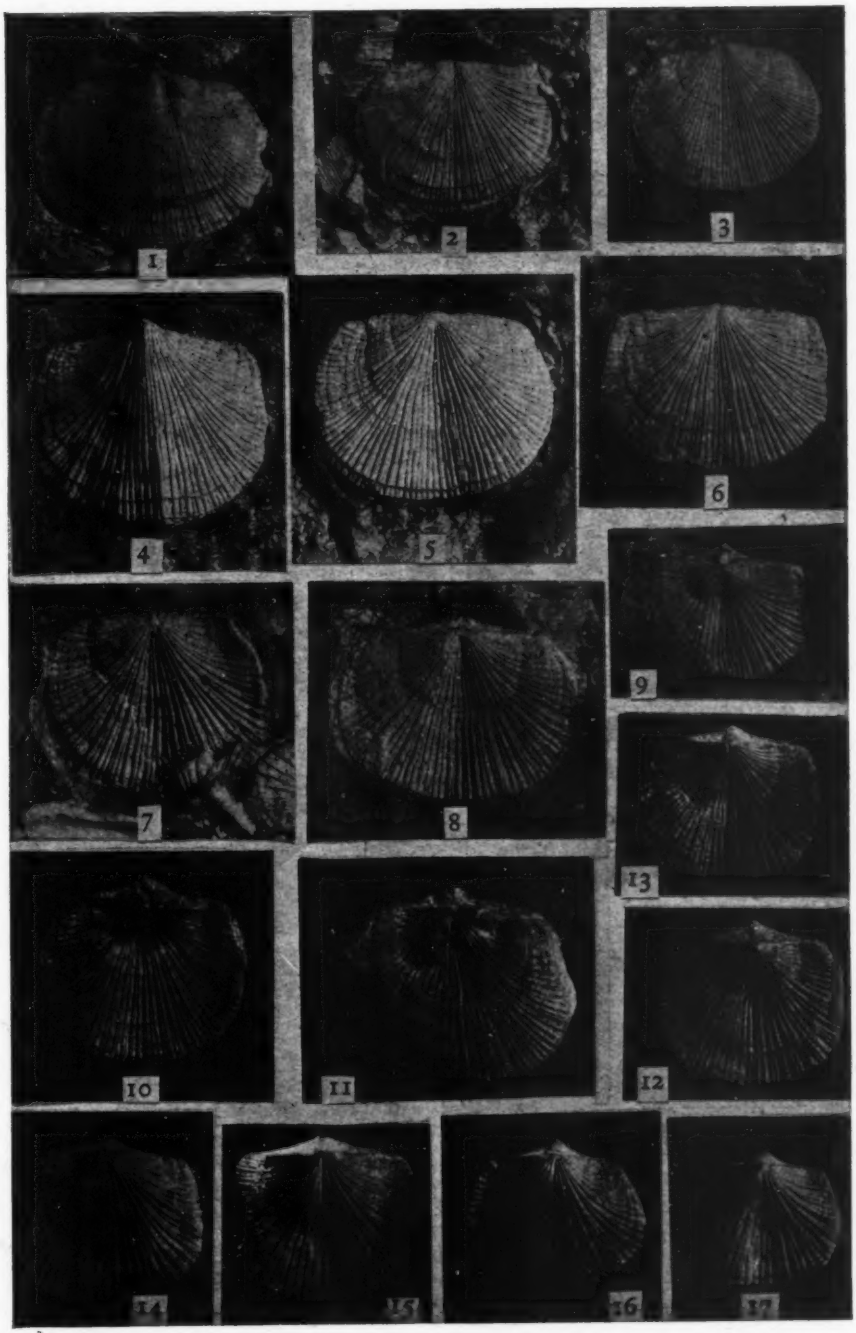
4–6—Onniella grandis Bancroft, n. sp. *4*, Cast from external mould of ventral valve, ×2; *5*, *6*, casts from external moulds of dorsal valves, ×2; all from the type locality, west of Hatton, Shropshire. (p. 217)

7–9—Onniella aspasia Bancroft, n. sp. Casts from external moulds of dorsal valves, ×2; all from the type locality, west of Wistanstow, Shropshire. (p. 217)

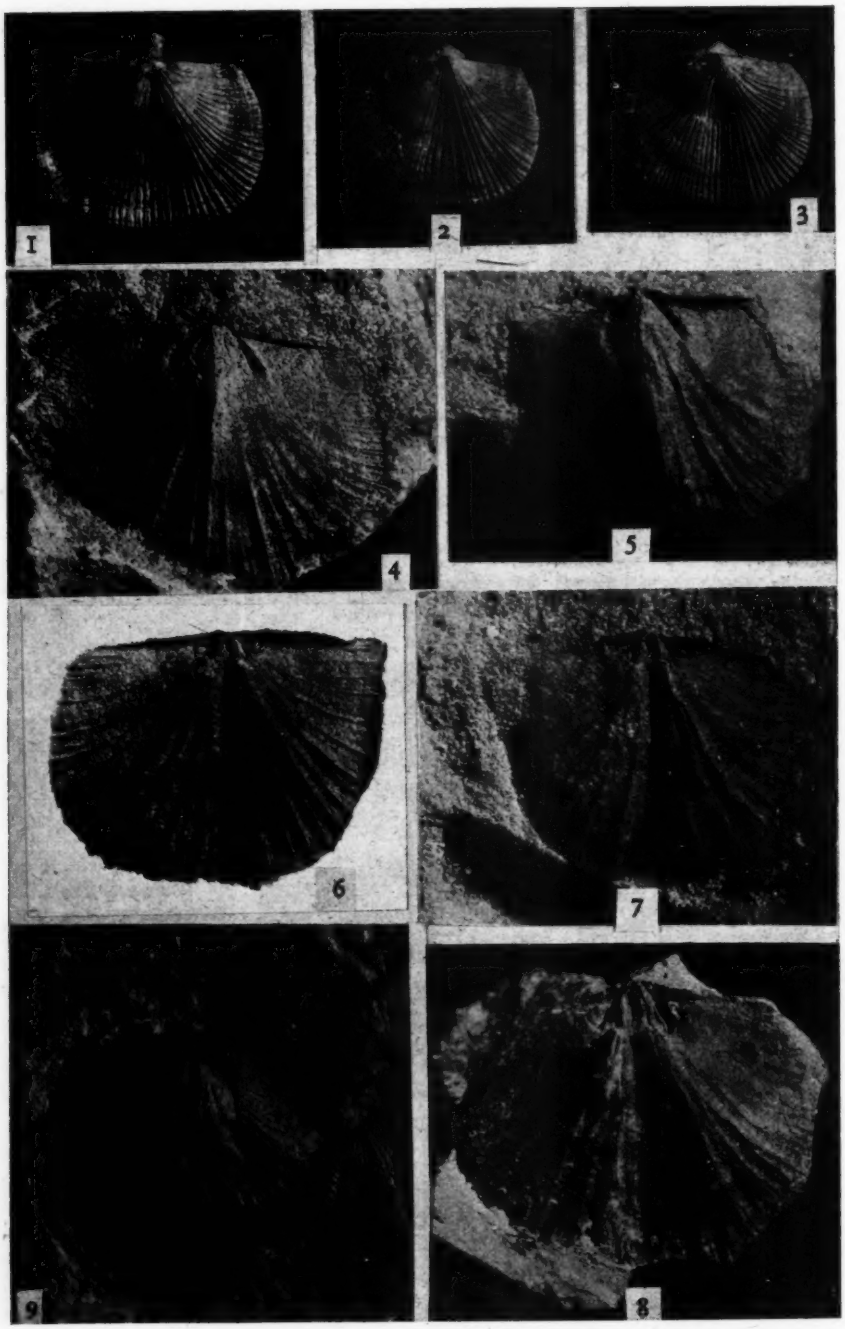
10–13—Onniella depressa Bancroft, n. sp. Dorsal aspects of conjoined valves from the type band in the Onny River section, ×2. All the specimens have the valves partially collapsed or buckled. (p. 218)

14–15—Onniella sinuata Bancroft, n. sp. Dorsal aspects of conjoined valves from the type bed in the Onny River (Bancroft Coll.: Py3), ×2. In both specimens the valves are partially collapsed and buckled. (p. 222)

16–17—Onniella bröggeri Bancroft. Dorsal aspects of conjoined valves from the type bed in the Onny River, Shropshire (Bancroft Coll: Pc), ×2. (p. 222)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

Type locality and horizon.—In the section by the south bank of the River Onny, 900–970 feet east of the east end of Burrell's Coppice, Horderley. The type specimens are from the large ledge, 13.5 feet from the east end of the section, in the zone of *O. depressa*.

Affinities.—Genetically *O. depressa* is situated near the origin of a branch diverging from the main line through *O. reuschi*, *O. grandis* and *O. inconstans*. The ribbing statistics are closely similar to those of *O. aspasia*, a somewhat earlier divergent species, and intermediate between those of *O. grandis* and *O. inconstans*. *O. depressa* is distinguished from the other members of this group by the relatively long shell and rounded contour of normal individuals.

ONNIELLA INCONSTANS Bancroft n. sp.
Plate 31, figures 1–3

Shell transversely subrectangular to nearly subquadrate. Anterior margin feebly rounded. Hinge wide or only moderately so. Ribbing moderately fine for the group. [3a⁻1⁻a⁻1⁻], [3a⁻1⁻a⁻], [3a⁻1⁻b⁻], 3a⁻1⁻a⁻, [3a⁻1⁻a°], 3a⁻2⁻, [3a⁻3⁻], [3a⁻1°], 3b⁻1⁻, [3b⁻1°], 3c⁻, [3d⁻], [3a°1⁻], 3a°, [3a°1°] terminal. 1b⁻)1a°:H3, 2a⁻1⁻)2b⁻:H2, 2b⁻1⁻)2a°:H, 3b⁻1⁻)3c⁻:H. Growth-lines variable, usually weak. Interspaces between ribs with fine, closely set concentric striæ.

Variation.—In mature individuals the prevailing type is only slightly transverse and approximates to a subquadrate form. Such shells have wide hinges and broad, nearly straight or gently rounded anterior margins. Associated with these shells is a variety of wide forms varying from weakly to strongly transverse, but in other respects agreeing with the norm. Both the normal and transverse types are sometimes associated with narrow hinges, and more strongly curved anterior margins. Slightly immature shells and young individuals have the transversely rectangular contour characteristic of *O. reuschi*.

It is almost impossible to define the variation in the convexity of the valves of this species, as the shells are only partially filled and usually much buckled about the growth lines. For the most part they seem to be about as deep as in *O. reuschi*, though some of the larger dorsal valves are evidently more strongly convex. The dorsal sinus is usually somewhat deeper, and in the early growth stages more angular than in that form. It becomes shallower towards the front and is often obliterated in a wide peripheral zone.

The internal characters are known only from a single interior of the dorsal valve. This shows a large subovoid cardinal process filling nearly the entire space between a pair of robust crural plates. The latter have small crural pits. The muscle area is defined by a strong boundary ridge, and the subequal anterior and posterior scars are separated by an oblique partition.

Type locality and horizon.—In a small exposure in the north bank of the River Onny, east of Horderley, c. 250 feet east of the 'y' in 'Onny' on the 6-inch Ordnance Survey map, and 62 paces east of the junction of the stream and gutter (Bancroft Coll: Pw1). The horizon is in the zone of *Onnia cobboldi*, about 15 feet above the typical locality of the index.

Affinities.—This species is distinguished from earlier species of *Onniella* by the pro-

EXPLANATION OF PLATE 31

FIGS. *1–3—Onniella inconstans* Bancroft, n. sp. Dorsal aspects of conjoined valves from the type band in the Onny River, Southeast Shropshire (Bancroft Coll: Pw1), ×2. (p. 221)

4–7—Horderleyella plicata Bancroft. *4*, *6*, *7*, Internal moulds of a ventral and two dorsal valves from the old quarry in Brokenstones Plantation, near Horderley, Shropshire (V10), ×2; *5*, internal mould of ventral valve from the quarry 500 feet south of the farmhouse at Coston, Southeast Shropshire (Coston 21a), ×2. (p. 236)

8—Horderleyella corrugata Bancroft, n. sp. Internal mould of dorsal valve from the type locality above Glenburrell, Horderley (Y22), ×2. (p. 237)

9—Heterorthis retrorsistria M'Coy, var. Internal mould of ventral valve from the dark shales of the tramway cutting by the south bank of the Teirw at Pandy, Glyn Ceiriog, Denbighshire (Bancroft Coll: Glyn 3'j), ×2. (p. 205)

gressive character of its ribbing. The forms from higher horizons in the Onnian seem also to be less progressive in this respect, but the statistical data are not adequate to show whether this is true of all the relations. Apart from the ribbing the characteristic form of the valves is the most distinctive feature.

ONNIELLA SINUATA Bancroft, n. sp.
Plate 30, figures 14, 15

Shell subrectangular, c. 12.5 mm. wide, rather coarsely ribbed for genus. Hinge wide. Dorsal valve with persistent angular sinus, or same becoming shallow towards periphery. [3a^{-1}-a^{-1}-], 3a^{-1}-a^{-}, [3a^{-1}-a°], 3a^{-2}-, [3a^{-1}°], [3b^{-1}-], 3b^{-}, [3c^{-1}-], [3c^{-}], [3b°], [3a°1-], [3a°], [3a°1°] at periphery. 1b^{-})1a°:H1, 2c^{-})2a°:M1, 3a^{-1}-a^{-})3a°:L3, 3c^{-})3a°:L1, 3a^{-1}°)3a^{-1}-a^{-}:L1. Crural plates robust. Dorsal muscle area with fine peripheral ridge; anterior and posterior scars deeply impressed, separated by transverse partition; anterior scar large; posterior scar very small. Internal ribbing sometimes (generally?) restricted to broad peripheral zone. Ventral interior unknown.

Material.—The material consists of conjoined valves in a calcareous mudstone, and is clearly affected by load pressures. It is probable that the depth and angularity of the dorsal sinus have been augmented by this distortion. The description of the dorsal interior is based upon a single internal mould obtained from a few feet below the typical horizon.

Type locality and horizon.—In the north bank of the River Onny, c. 1300 feet east of the east end of Burrell's Coppice, 29–30 paces east of junction of river and gutter, a small exposure under a sycamore tree. The horizon is in the zone of *O. sinuata*.

Associated fauna.—Chasmops macroura, Sowerbyella cylindrica, Dolerorthis, cystoids.

Affinities.—The characters of our solitary dorsal interior present the strongest affinities with the Onnian *O. bröggeri*. It is probable that these species are in direct line of descent. The ribbing relations, which are certainly very close to those in *O. bröggeri*, support this view. Comparison of the ribbing statistics in this species and the *O. reuschi–O. grandis* suite do not suggest strong genetic affinity.

ONNIELLA BRÖGGERI Bancroft
Plate 30, figures 16, 17

Onniella bröggeri BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 56, pl. 2, figures 1–5.

Shell transverse, approaching subrectangular, with variable hinge, c. 11 mm. wide. Dorsal valve with deep, angular mesial sinus. Ventral valve angulated about mesial line. Ribbing rather coarse and uneven for the genus. [3a^{-1}-a^{-1}-], 3a^{-1}-a^{-}, [3a^{-2}-a^{-}], 3a^{-2}-, [3a^{-1}°], 3b^{-1}-, 3c^{-}, 3a° terminal. 2a^{-1}-)2b^{-}:H1, 3a^{-1}-a^{-})2a°:H3, 3a^{-1}-a^{-})2b^{-}:H2, 3a^{-1}°)3a^{-1}-a^{-}:L1, 3a^{-1}°)3b^{-1}-:L2, 3b^{-1}-)3c^{-}:M, 4a°2°)4a°2^{-}:H. Interspaces between ribs with fine concentric striæ and fine interribs. Interior of dorsal valve with *Resserella*-like crural plates and deeply impressed adductor scars; the posterior scar conspicuously small and separated from the large anterior scar by a strong transverse ridge. Ventral muscle area small, partly confined by a pair of short, massive dental plates; a pair of vascular trunks traversing muscle area and uniting with traces of internal ribbing; a third, mesial trunk sometimes present. Internal ribbing sharply defined in broad peripheral zone, becoming obscure in inner parts of the shell.

Material.—The typical material consists of conjoined and partly collapsed valves from a rubbly calcareous mudstone. This is supplemented by a number of good internal moulds from a decalcified mudstone at nearly the same horizon. The description of the interior of the ventral valve is based upon the latter.

Variation.—That this is a true small species seems evident from the uniform size of the shells from the type deposit. The rather larger, decalcified fossils from the neighboring locality must, therefore, be regarded as a distinct variation. The latter shells attain abnormally to a width of 14.5 mm.

The shells from both localities are always clearly but never strongly transverse; they have the front margin nearly straight or gently curved, and the hinge rather short or moderately wide. Normally the width is greatest in front of the middle. The following are measurements of three dorsal valves from the type locality: width of hinge, 6.5, 7.0, and 8.5 mm.; width of shell, 11, 11, and

11 mm.; length of shell, 8.75, 8.5, and 8.5 mm.

The growth lines are usually faint except in a narrow peripheral band, where there is often a group of closely set lines producing an imbricated effect.

Type locality and horizon.—In a ledge of calcareous mudstone extending across the River Onny and a ledge on the south side of the stream, about 120 feet west of the west end of the cliff section in Onny shales (Bancroft Coll: Pc). The decalcified material is from a small exposure in the roots of a tree on the north side of the stream; this exposure is in line with the ledge Pc, and a few feet higher in the sequence. Both localities are in the zone of *Onnia gracilis*.

Associated fauna.—The common associates are *Onnia gracilis*, *Ampyx* aff. *A. rostratus*, *Remopleurides*, *Calymene* and *Chonetoidea*. *Sowerbyella cylindrica* also occurs at this horizon.

Affinities.—The affinities subsisting between this species and *O. sinuata* are noted in the description of the latter. Apart from the somewhat larger size of the earlier form the most distinctive character is the relation $3a^{-}1^{-}a^{-})2b^{-}$.

With reference to the general characters of the *O. bröggeri* group we note the size of the shells is much smaller than in the *O. reuschi* group, and the internal characters are more strongly developed and specialized. The presence of vascular sinuses in the ventral valve is particularly noteworthy, as they show that the small size of the shell is a mature character and does not result from selective current action. *O. bröggeri* and its allies are, therefore, true dwarfs. The variation in the size of the crural plates and muscle scars, and the presence of vascular trunks may in themselves have small value in phylogeny; they become significant when considered in relation to the size of the shells.

Genus CRYPTOTHYRIS Bancroft, n. genus

Genotype, *Resserella paracyclica* Bancroft, 1928.

Dorsal valve feebly convex, without mesial sinus. Ventral valve shallow to moderately convex, always much deeper than the dorsal; umbo of ventral valve large, depressed, concealing most of the low ventral interarea. Hinge very short, to moderately wide for dalmanelloids. Ribbing approaching *Rhipidomella hybrida* type, with a submesial rib (1-lt. or 1-rt.). Dorsal interior as in typical *Onniella* (with large anterior, and small posterior adductor scars). Ventral interior *Resserella*-like but with delicate divaricator trunks. Actonian.

Variation.—This genus is represented by two Actonian species, *C. paracyclica* and *C. cyclica*, Bancroft (1928); the only distinction so far noted being in the width of the hinge line. The assemblages do not seem to exhibit notable divergences from the normal characters of the genus.

Affinities.—*Cryptothyris* is the earliest member of a line leading through *Mendacella* Cooper, to the *hybrida* suite of *Rhipidomella* in the Silurian. It differs from *Mendacella* and resembles normal dalmanelloids in the relatively greater depth of its ventral valve when compared with the dorsal, and in its narrow, *Resserella*-like ventral muscle area. These distinctions are still more marked when *Cryptothyris* is compared with *Rhipidomella hybrida* or the Devonian species of *Rhipidomella*.

Family HETERORTHIDAE Schuchert and Cooper
Subfamily HARKNESSELLINAE Bancroft

This subfamily is equivalent to the genus *Harknessella* as conceived by Reed (1917), to the Harknessellinae of Bancroft as now emended, and to the Harknessellinae as emended by Schuchert and Cooper together with the genus *Horderleyella*.

The essential characters of the subfamily are as follows:

1, The shell is widest at the hinge, and the posterolateral angles are normally produced into short wings.

2, The valves are subequally convex or the dorsal valve is deeper than the ventral; the mesial line is always more strongly curved in the former. The ventral valve may be nearly plane or concave.

3, Sector III forms the axis of the lateral fold; the externals in this sector are better developed than in Dalmanellidae. $3a^{-}1^{-})3a^{\circ}:L$, $3b^{-})3a^{\circ}:L$, and $3c^{-})3b^{\circ}:L$ are characteristic.

4, The cardinal process is an ovoid body, and often supports a mesial ridge. The myophore and shaft are normally inseparate.

5, The anterior faces of the crural plates are formed by a pair of parallel, subparallel, or convergent edges. These edges support the crura at their extremities.

6, The dorsal adductor scars are produced posteriorly, forming cavities in the notothyral platform (adductor pits).

The rib system in Harknessellinae is a modification of the type found in Dalmanellidae, the most distinctive character being the large sector III, which forms the axis of the lateral fold. Owing to this position and the steepness of the external limb of the lateral fold the derivatives of 3a° are very numerous: the larger sector 3A° and the presence of 3b° and sometimes of 3c° and 3d° in Harknessellinae affords a means of distinguishing the family from the Dalmanellidae. Only in the most primitive genus (*Horderleyella*) does the rib system approximate to the dalmanelloid type, and in this, as in other Harknessellinae, the trend is towards the specialized harknesselloid relations.

Sectors I and II present the same general relations as in Dalmanellidae, but in the variable sectors IV, V and VI the dalmanelloid type is usually much modified, and the correlation of the primaries may be attended with some difficulty. The relations which are constant or nearly constant in Harknessellinae are as follows:

$3a^{-}1^{-})3b°:L$, $3b^{-})3b°:L$, $3a^{-}1^{-})3b^{-}:H$, $3a^{-}1^{-}a^{-})3b^{-}1^{-}:H$, $3a^{-}1^{-}a^{-})3a^{-}2^{-}:H$.

$3a^{-}1^{-})3a°:L$, $3b^{-})3a°:L$, $3a^{-}1^{-}a^{-})3a°:L$, $3c^{-})3a°:L$, $3c^{-})3b°:L$, $3c^{-})3a°1°:L$.

$3a°)4a^{-}1^{-}:H$, $3a°1°)4a^{-}1^{-}a^{-}:H$, $3c^{-})4a^{-}1°:L$.

$4a^{-}1°)4a^{-}1^{-}a^{-}:H$.

In some early forms (*Horderleyella*) the valve form approximates to the type found in dalmanelloids, but even amongst these the peculiar surface foldings which characterize the specialized genera are always present in the inceptive state. In the later and more characteristic genera independent lateral folds are present in both valves, and there is always a more or less conspicuous mesial fold on the ventral. There can be no difficulty, therefore, in distinguishing between Harknessellinae and Dalmanellidae without reference to the internal characters, ribbing or relative convexity of the valves.

In late gerontic individuals the antero-lateral angles become rounded, so that the valves are no longer widest at the hinge; at the same time the folds and sinuses become obscure, and the shells assume a strongly dinorthoid aspect. This transformation is the culminating stage in the morphological history to which I now advert.

The most primitive Harknessellinae that have been studied are the Costonian *Horderleyella* and *Harknessella*. In the former the ribbing relations are intermediate between those in the later Harknessellinae and the Dalmanellidae, and these affinities are further evinced in the generalized character of the form. In the later, and much larger species of *Horderleyella* the ribbing relations approach much closer to those characteristic of the normal Harknessellinae. The characteristic harknesselloid type of shell is first seen in the Costonian *Harknessella*, a genus with a specialized type of crural plate which is again found in late species of *Reuschella*. There seems to be no direct relationship between these groups, and, as far as is known, *Harknessella* dies out in the Costonian.

The basal Harnagian horizon is followed by a great hiatus in the British record, but the family appears in great force in the lower Soudleyan, an horizon characterized by the larger and more advanced type of *Horderleyella*. A little higher in the same stage *Horderleyella* disappears, and is immediately replaced by *Reuschella*, a genus which combines an advanced shell form with an equally specialized type of ribbing. The crural plates, on the other hand, are built on the plan of *Horderleyella* and in young shells are identical with those in the mature *Horderleyella*. There is, therefore, good reason for assuming that *Reuschella* is derived from *Horderleyella*, though there is no evidence of descent from its immediate precursors.

The highest horizons in the Soudleyan are marked by the appearance of a group of *Reuschella* which in many respects are the most specialized of the Harknessellinae; in the *H. horderleyensis* group the characteristic folds and sinuses are most strongly developed, and the ribbing relations are most

remote from the dalmanelloid type. The *H. horderleyensis* group represents a culminating stage in the trend away from the Dalmanellidæ.

The ribbing relations in the other species of *Reuschella* rarely attain to these distinctive characters, though it is in the group of *R. bilobata* that the internal characters assume their most extravagant development.

The history of the Harknessellinae is interrupted during the lower Longvillian, but at the conclusion of that stage *Reuschella* returns, and is represented by a continuous series of species until the end of the Actonian. No striking general transformation is observed during this period, but in the *R. bilobata* group the most advanced types show a progressive trend towards the dinorthoid type of shell in which the ventral valve is concave, and the folds and sinuses are obliterated. The advanced Actonian forms are also notable for their large, flattened muscle areas in the ventral valve, and the absence of adductor pits in the notothyral platform.

TABLE IX

	2a⁻1⁻)2a°	2b⁻)2a°	2b⁻1⁻)2a°	2c⁻)2a°	3a⁻1⁻)3a°	3b⁻)3a°	3c⁻)3b°1°	3a°1°a°)3a°1⁻	4a⁻1⁻)3b°	4a⁻1°)4a⁻1⁻	4a⁻1°)4b⁻
Group of *Reuschella horderleyensis*	H	H	H	H	L	L	L–M	[M]–H	L	M–H	M–H
Group of *Reuschella bilobata*	H	H	L	L	L	L	L–M	H	L	M–H	M–H
Horderleyella	M	H	L	L	M	L–M	H	L	H	L–[H]	L–[H]
Harknessella	L	L–M	L	L	L	L	H	L–H	M–H	L	M–H
Post-Llandeilian Dalmanellidae	H	H	L	L	H	H	H	L	H	L	L

Genus HARKNESSELLA Reed, 1917

Genotype, *Orthis vespertilio* Sowerby, 1839.

Harknessellinae with the valves subequally or unequally biconvex. Crural plates more or less completely attached to the interior of the shell throughout their length, with the edges in front of the fulcral plates subparallel. Socket lines divergent; presocket lines long and subparallel, straight or angulated by crural pit. Ventral muscle area bilobate, usually with strongly defined divaricator scars, and narrow, undifferentiated adductor tract; lateral boundary ridges parallel or divergent. Costonian to basal Harnagian.

Observations.—The structure of the crural plates in *Harknessella* is very characteristic and constitutes the chief discriminating character of the genus. They may be regarded as consisting of a pair of low *Dalmanella*-like plates, from the extremities of which arise a pair of parallel extensions, the ventral edges of the latter being inclined towards the front. These apparently accessory structures are really homologous with the apices of the crural plates in dalmanelloids and support the crura at their anterior extremities. Corresponding to the divergent posterior edges of the ventral aspect are the divergent socket lines of internal moulds, whilst the presocket lines correspond to the anterior edges. The presocket lines may be parallel or angulated by the crural pit; in the latter case the lines joining the extremities are subparallel. In the other harknesselloid genera the presocket lines converge towards the front.

The other distinctive characters are the subparallel or anteriorly divergent boundary ridges of the muscle area, and the relations 2a^{-1-})2a° and 2b^{-})2a°. It is not certain, however, that the latter are consistent in all the Costonian forms.

Harknessella is a very variable genus embracing a number of species and probably more than one line of descent. The earliest form (*H. subplicata*) has deep crural pits and coarse ribbing, so that it bears a close resemblance to *Horderleyella*. The essential difference between this species and *Horderleyella* lies in the fact that the lines joining the extremities of the presocket lines are subparallel or divergent in the one, and convergent in the other. Most of the later species of *Harknessella* (e.g. *H. vespertilio*) are large, finely ribbed forms with long presocket lines. No post-Harnagian forms are known, but the characteristic type of crural plate is seen in some Soudleyan species referred to *Reuschella*. The half-grown stages in these species have the *Horderleyella* type of crural plate.

The species which are used as zonal indices are *H. subplicata* and *H. subquadrata*.

Harknessella subplicata
Bancroft

Plate 32, figure 9; plate 33, figures 1–4

Harknessella subplicata Bancroft, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 12, p. 182, pl. 1, figs. 7–10.

Shell subrectangular, with small wings, c. 24 mm. wide. Dorsal valve moderately deep for the genus, with shallow, rounded sinus, or more rarely the sinus deeper and more angular; lateral folds broad and rounded. Ventral valve convex, much less so than dorsal, with low, rounded or subangular mesial fold; incipient lateral folds sometimes present. Surface covered with moderately fine, irregular, closely set ribs. [3a^{-1-}a^{-1-}], 3a^{-1-}a^{-}, 3a^{-2-}, 3a^{-1}°, 3b^{-1-}, [3b^{-1}°], 3c^{-}, 3c°, [3c°1°], 3b°1°, [3b°2°], 3a°1^{-}, 3a°2°, 3a°1°a° terminal. 2a^{-1-})2b^{-}: M, 2b^{-1-})2a°:L, 2c^{-})2a°:L, 3a°1°a°)3a°1^{-}: H, 4a^{-1-})3b°:H, 4a^{-1}°)4a^{-1-}:L, 4a^{-1}°)4b^{-}: H. Interspaces between ribs with very fine concentric striæ and few interribs, or concentric striæ apparently absent. Cardinal process slender, resolved into distinct myophore and shaft, or myophore and shaft inseparate. Crural plates rather small and delicate for genus, with large triangular crural pits, or crural pits shallow; presocket lines deeply angulated, parallel or divergent. Dorsal muscle area feebly defined or indefinite in front of platform; anterior and posterior scars inseparate. Ventral muscle area shallow, with very fine lateral boundary ridges; anterior margin usually obscure or indefinite; adductor and divaricator tracts defined by internal ribbing. Interiors of both valves traversed by sharply defined internal ribbing.

Variation.—The most important variations are associated with the crural plates and arise from the variable development of the crural pits. In the normal type these pits penetrate deeply into the plates, which are resolved basally into a pair of very slender laminæ by which the crural plate is attached to the shell. The posterior laminæ (fulcral plates) are short and widely divergent; the anterior pair are long and diverge at a lower angle. The internal moulds of such shells exhibit the large triangular fillings of the crural pits and delicate slots corresponding to the supporting laminæ. Rarely the crural pits are entirely filled by calcareous deposit when the basal plan assumes the type normal in the genus. A simi-

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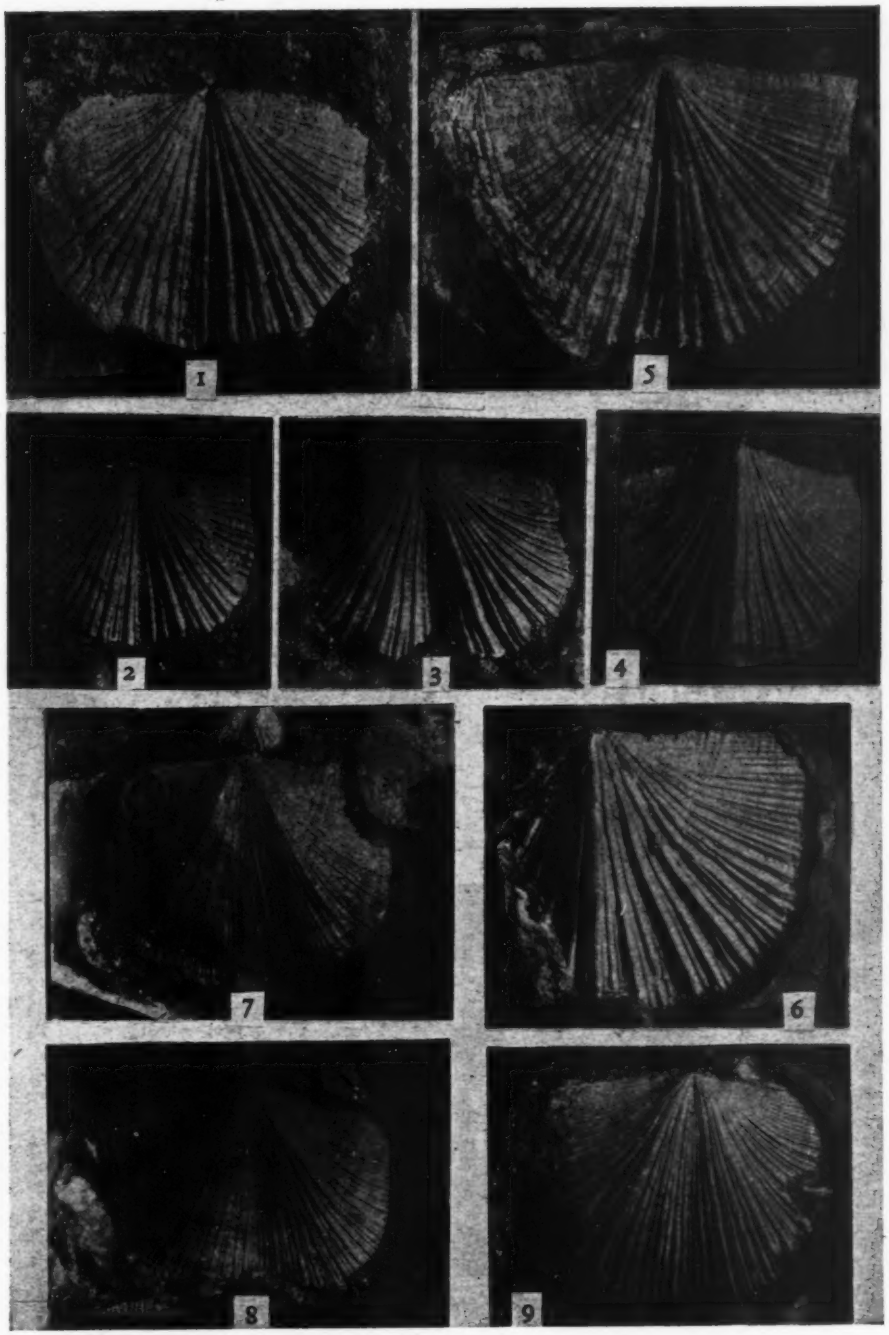
Explanation of Plate 32

Figs. *1–4—Horderleyella plicata* Bancroft. *1–3*, Casts from external moulds of dorsal valves from the type locality near Horderley (V10), ×2; *4*, cast from external mould of ventral valve from Coston 21a1, ×2. (p. 236)

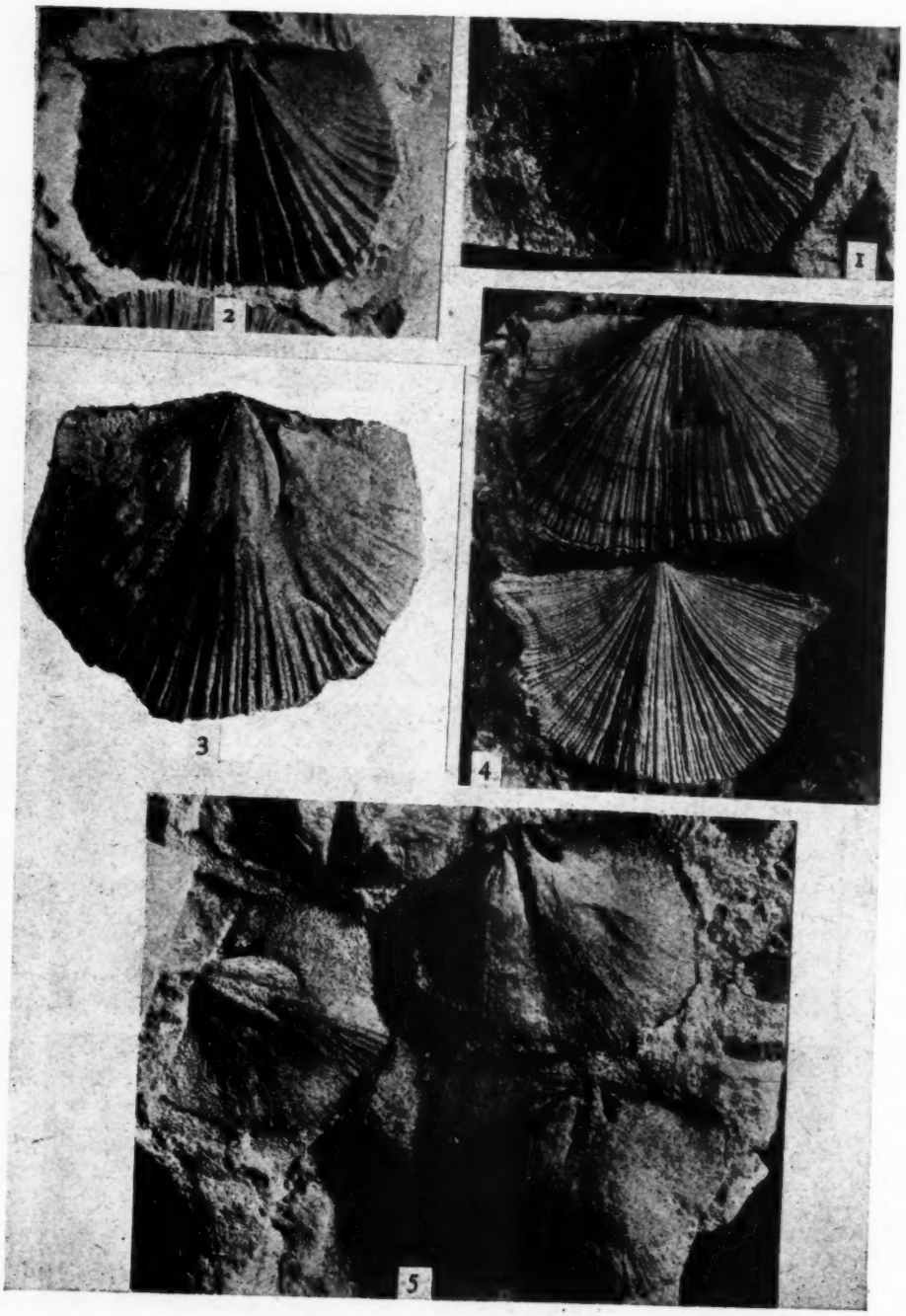
5, 6—Horderleyella corrugata Bancroft, n. sp. Casts from external moulds of a dorsal and ventral valve from the type locality at Horderley, Shropshire, ×2. (p. 237)

7, 8—Harknessella subquadrata Bancroft. Casts from external moulds of dorsal valves from the *H. subquadrata* zone of the quarry above Harnage Grange, near Cressage, Shropshire, both ×2. (p. 229)

9—Harknessella subplicata Bancroft. Cast from external mould of dorsal valve from the type locality (Bancroft Coll: Cressage 3a), ×2. (p. 226)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

lar range of variation affects the crural plates in young individuals, some shells exhibiting crural pits whilst in others they are quite absent.

The variation in the ribbing is less conspicuous than in most species. The list of terminals set out in the diagnosis must in this instance be regarded as exemplifying the type and not as a complete statement of variation.

The following are measurements of three dorsal valves: width at hinge, 23.0, 23–24 mm., and unknown; length of shell, 17.0, 18.5, and 19.0 mm.

Type locality and horizon.—In the gutter section at Bullhill, near Cressage, Shropshire, 510 feet south of Bullhill Cottage and about 20 yards from the junction of the gutter with the main stream (Bancroft Coll: Cressage 3a). In a pale yellowish sandstone of the Costonian. The cotypes are from the lowest 2½ feet of the section in the 'new' quarry (between the two coppices) above Harnage Grange (Bancroft Coll: Cressage 6a, 6b). Both localities are in the zone of *Harknessella subplicata* and immediately below the *H. subquadrata* zone.

Associated fauna.—The associates are *Calymene* sp., *Rafinesquina* sp., *Heterorthis* sp., *Wattsella* small sp., *Sowerbyella* sp., *Cliftonia andersoni.*

Affinities.—Of the species which may be compared to this form *H. vespertilio* is a much larger shell, the width varying between 30 and 35 mm. *H. vespertilio* is also distinguished by its relatively fine and even ribbing, by its large oval cardinal process, by the absence of crural pits, and the long, only slightly inclined presocket lines. A much nearer form is *H. confinis* Salter, as interpreted by Reed (1917, pl. 8, especially figs. 26, 27). This species is about the same size as *H. subplicata* and has very similar external characters. On the other hand, the strongly impressed ventral muscle area approaches the type found in *H. subquadrata* and is quite distinct from that in *H. subplicata.*

HARKNESSELLA SUBQUADRATA Bancroft
Plate 32, figures 7, 8; plate 33, figure 5; plate 34, figure 1

Harknessella subquadrata BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 12, p. 184, pl. 1, figs. 1–6.

Shell subrectangular, approaching subquadrate, with obscure wings, c. 24 mm. wide. Dorsal valve moderately deep for genus, with shallow rounded sinus, or sinus obsolescent; lateral folds involved in general curvature of shell, obscure or low and rounded. Ventral valve convex, without independent mesial or lateral folds, or same obsolescent. Ribbing very fine, approaching rafinesquinoid. 3a⁻1⁻a⁻1⁻, [3a⁻1⁻b⁻], [3a⁻1⁻a°], [3a⁻2⁻a⁻], 3a⁻2⁻, [3a⁻3⁻], 3a⁻1°, 3b⁻1⁻, 3b⁻, 3b⁻1°, 3c⁻, [3d⁻], [3d°], 3c°, 3b°, [3b°1°], [3a°1⁻a⁻], 3a°1⁻, 3a°1°, [3a°1°a°] terminal. 2a⁻1⁻)2b⁻:L, 3b⁻1°)3b⁻1⁻:M, 3c⁻)3b°1°:H, 4a⁻1°)4b⁻:M. Entire surface of valves traversed by very fine, concentric striae. Cardinal process situated in a cup-shaped concavity between the crural plates, consisting of more or less distinct myophore and shaft. Crural plates robust for the genus, without crural pits or same very shallow; pre-socket lines parallel or anteriorly divergent, rather short; adductor pits very small. Dorsal muscle area indefinite in front of crural plates, or large and more or less deeply impressed; anterior and posterior scars inseparate or obscurely defined, the latter triangular and rather wide for the genus. Ventral muscle area deeply impressed, bilobate, consisting of a pair of strongly defined divaricator scars, and a single narrow adductor impression. Interiors of both valves ribbed in a narrow peripheral zone, or the ribbing extending into the inner regions of the shell, but never entering muscle areas. Vascular sinuses sometimes present.

EXPLANATION OF PLATE 33

FIGS. *1–4*—*Harknessella subplicata* Bancroft. *1, 3,* Internal moulds of ventral valves, ×2; *2,* internal mould of dorsal valve, ×2; *4,* cast from external moulds, ×2; all from the type locality (Cressage 3a). (p. 226)

5—*Harknessella subquadrata* Bancroft. Internal moulds of dorsal and ventral valves from the *H. subquadrata* zone of the small quarry above Harnage Grange (Cressage 6); ×2. (p. 229)

Variation.—The characteristic finely ribbed shells of the type band are associated with more coarsely ribbed variations which seem to be referable to the same species. The extreme variations are quite as coarsely ribbed as *H. subplicata*, from which our species is derived. A series of intermediate forms, some of which seem to be distinct varieties, link the extreme variations. The terminal ribs as set out in the diagnosis are those of typical finely ribbed shells.

The dorsal muscle area is sometimes large and deeply impressed, with broadly subtriangular posterior impressions; this type occurs only in small gerontic shells and is a concomitant of dwarfing. Corresponding to this type is a very strongly impressed type of ventral muscle area. In the normal type the adductor tract is often without a definite anterior boundary, and in some specimens it conducts to an elongated vascular fossa in front of the muscle area; in others it bifurcates, giving rise to a pair of vascular sinuses; rarely it is divided longitudinally into a pair of scars. In the narrower types of muscle area the lateral margins are nearly straight and narrowly divergent; in the wider forms they are parallel or convergent in front of the extremities of the dental plates. The divaricator scars are always deeply impressed, and strongly lobed in front, and the single scars are always wider than the adductor tract.

The following are measurements of three dorsal valves: width at hinge, 21.0, 21.0, and, 25.5 mm.; length, 15.5, 16.5, and 19.5 mm.

Type locality and horizon.—In sandy limestones overlying the zone of *H. subplicata* in the gutter section in Bullhill, near Cressage (Bancroft Coll: Cressage 3f). The material illustrated in this paper is from the bed 6c in the small quarry above Harnage Grange:

		Feet
6e	Coarse grit at top of section, *Smeathenella* aff. *harnagensis*	1.5
6d	Incoherent gritty sand, *Smeathenella* aff. *S. harnagensis*, *Dinorthis* aff. *D. flabellulum*, *Schizophorella*, rhynchonelloids	2.0
6c	Bastard limestones, *H. subquadrata*, *Heterorthis*, *Cliftonia andersoni*.	
6a, b	Bastard limestones and calcareous sandstones with *H. subplicata* and *Rafinesquina* sp.	c. 2.5

Associated fauna.—This species is associated with the same fauna as *H. subplicata*.

Affinities.—*H. subquadrata* is derived from *H. subplicata* in the underlying zone, and itself gives rise to a large species from a somewhat higher horizon (Cressage 31d). The stratigraphical relations of the three species are seen in Wylde's quarry, east of Stevenshill, Cressage District, where the succession is as follows:

		Feet
Harnagian.		
31i	*Sowerbyella* grit (at top of quarry)	c. 10
31h	Highly calcareous grit, *Smeathenella*, *Harknessella* aff. *vespertilio*, *Dinorthis* sp., *Cliftonia andersoni*, *Dolerorthis*	c. 2
Costonian.		
31g	Shaly beds.	
31f	Silver-grey crumbly grits. *Dinorthis* aff. *D. flabellulum*.	
31e	Yellow crumbly grits. *Horderleyella* horizon at base.	
31d	White and yellow grit *Harknessella* aff. *H. subquadrata*., *H.* cf. *H. vespertilio*, *Rafinesquina*.	less than 30
31c	Flaggy muddy beds full of *Rafinesquina*.	
31b	Muddy limestone full of *H. subquadrata*.	
31a	*H. subplicata* beds.	

The derivation of *H. subquadrata* in *H. subplicata* is adduced from their association with the same fauna, their closely similar size, ribbing relations and external morphology, and the close approximation of the ribbing types in abnormal variations. The main distinctions between these species, which are partly attributable to the change in sedimentation, are as follows:

1, *H. subquadrata* is much more finely ribbed than *H. subplicata*.

2, The crural plates are more massive in *H. subquadrata*, and the crural pits are virtually absent. In *H. subplicata* the crural plates are delicate and usually have deep crural pits.

3, The ventral muscle area is deeper and more highly differentiated in *H. subquadrata*.

4, The internal ribbing is more strongly developed in *H. subplicata*.

The large finely ribbed species from Cressage 31d may be regarded as a giant form of *H. subquadrata* in which the ribbing characters have remained stationary. The interior of this species is distinguished by the large, flattened muscle area in the ventral valve.

HARKNESSELLA VESPERTILIO (Sowerby)

Orthis vespertilio SOWERBY, 1839, in Murchison, Silurian system, p. 640, pl. 20, fig. 11.

Shell large, transverse, with convergent lateral margins and small or obscure independent wings; 30–37 mm. wide. Dorsal valve moderately convex, with deep, rounded or subangular sinus, and broad independent lateral folds; posterolateral sector broad and weakly concave. Ventral valve variably convex, with a conspicuous subangular mesial fold bounded by a pair of more or less clearly defined lateral sinuses; lateral folds wide and somewhat obscure. Ribbing fine, without strongly differentiated primaries and secondaries. Cardinal process without distinct myophore and shaft, supported on a flattened notothyral platform. Crural plates with only obscure traces of crural pits, or same absent; presocket lines conspicuously long, parallel and only weakly inclined towards the front. Dorsal muscle scars narrow, extending far back between crural plates but not forming adductor pits. Ventral muscle area bilobate, deeply impressed, with a sharply defined adductor tract. Internal ribbing marginal or extending into middle region of shell, never penetrating ventral muscle area.

Variation.—Apart from the variable inclination of the lateral margins and the convexity of the ventral valve this is a very constant and sharply defined species. The ventral valve is always somewhat less convex than the dorsal, and usually has a more or less pronounced general convexity. In some individuals, however, the convexity is conspicuous only in the mesial fold. Young individuals are strongly transverse and subtrigonal. The following are measurements of two mature dorsal valves: width of shell at hinge, 32.5, and 37.5 mm.; length of shell, 25.0 and 22.5 mm.

Type locality and horizon.—Sowerby's shells were from 'Coston near Clunbury' and were associated with *Heterorthis patera* and *Dinorthis flabellulum*. The coarsely ribbed *Dinorthis* and *Harknessella* are associated at only one horizon in the Coston area, and that horizon is accessible in a single good exposure which we may assume to be the type locality. This may be defined as follows: In the *Heterorthis patera* grits by the north side of the cartway, 140 feet east of the building at Coston, and a few feet east of the gate leading to the building.

Affinities.—Large shells of *Harknessella* with similar characters to *H. vespertilio* occur at several horizons above the *H. subquadrata* zone. For the most part these species are associated with distinctive faunal elements and are generally to be distinguished by the absence of strongly convergent lateral margins. The species from the Hollies Farm is further distinguished by the absence of independent folds and sinuses on the ventral valve, by its rounded or subparallel lateral margins, and by its somewhat coarser ribbing. The associates of this species are *Heterorthis* small sp., *Cliftonia andersoni*, and a leptænoid.

H. vespertilio is distinguished from *H. subquadrata* by its larger size, its somewhat coarser ribbing, its narrow, pointed adductor scars in the dorsal valve, and its long presocket lines.

Genus SMEATHENELLA Bancroft

Smeathenella BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 12, p. 177.

Genotype *S. harnagensis* Bancroft.

Shell strophomenoid, with small wings. Dorsal valve feebly convex, with persistent mesial sinus and lateral folds, or the same restricted to immature stages. Ventral valve slightly convex to concave, with narrow, angular mesial fold, or mesial fold becoming obsolete. Dorsal interior with *Heterorthis*-like cardinalia; cardinal process fine; socket lines narrowly divergent, forming a gentle curve with the presocket lines; crural pits absent. Adductor scars very narrow, the posterior scars forming acutely angular extensions between the crural plates. Ventral muscle area flattened, lozenge-shaped or subpentagonal; adductor and divaricator areas inseparate. Costonian and basal Harnagian.

Observations.—The most distinctive features of this genus are the shallow valves and the curved, narrowly convergent crural plates.[1] The form varies between that of an

[1] The cardinalia in *Smeathenella* are built upon the *Harknessella* plan, their distinctive features arising solely from the reduced depth of the valves. This conduces to the suppression of the crural pits and the cementation of the crural plates to the base of the shell throughout their

Harknessella with abnormally depressed valves, and a type in which the normal harknesselloid characters are nearly entirely obliterated, the mesial fold alone persisting as a characteristic feature. Even this feature, however, is sometimes obsolete, so that the shells are superficially indistinguishable from strophomenoids.

Smeathenella is known first in the zone of *Horderleyella plicata*, where it is represented by the strophomenoid form, *H. strophomenoides*. The form from the basal Harnagian, *S. harnagensis*, has the depressed harknesselloid form and deeper valves; it seems quite clear, therefore, that the forms do not lie upon a single line of descent.

SMEATHENELLA STROPHOMENOIDES
Bancroft, n. sp.
Plate 34, figures 3–6

Valves long, with *Rafinesquina*-like contour and small, angular wings; 26–32 mm. wide. Dorsal valve very weakly convex, with narrow impersistent mesial sinus and lateral folds, the same becoming obsolete between the notothyral platform and the middle of the shell. Ventral valve feebly convex to feebly concave, with very narrow, angular mesial fold, the same coterminous with the dorsal sinus; lateral folds and sinuses restricted to very early growth stages. Ribbing moderately fine, irregular, consisting of several alternating series of finer and stronger ribs; the principal ribs not conspicuously stronger than others. Dorsal cardinalia small and very delicate; cardinal process consisting of a small, elevated, ovate body; crural plates slender, very narrowly divergent; socket lines feebly convex to the sides. Dorsal muscle scars defined by internal ribbing, or margins obscure; posterior and anterior scars inseparate. Adductor pits minute or absent. Interior of ventral valve with a pair of narrowly divergent dental plates united with a pair of subparallel ridges at the sides of muscle area. Ventral muscle area feebly impressed; anterior margin indefinite; divaricator and adductor areas feebly defined or obscure. Entire interiors of both valves traversed by clearly defined internal ribbing.

Variation.—This species embraces two contemporaneous local varieties, the typical, or Coston variety and the variety from Horderley. The salient characters of these varieties are as follows:

1, The Horderley variety is somewhat larger than the Coston variety, the former attaining to a length of 29 mm., whilst the latter does not exceed 27 mm., and is generally much smaller.

2, The ventral muscle area in the Coston variety is always very small, and the dental plates very narrowly divergent. In this variety the composite plates at the sides of the muscle area may be feebly angulated at the extremity of the dental plates, or they may be curved. These features are found in immature shells and in some mature shells from Horderley, but in the mature shells the dental plates are longer and more robust, and the muscle area is much larger.

3, In some of the Horderley shells the internal ribbing is restricted to a narrow peripheral zone.

4, The dorsal cardinalia exhibit differences comparable to those in the ventral valve.

These variations seem to arise from the operation of local influences upon assemblages temporally isolated in the littoral

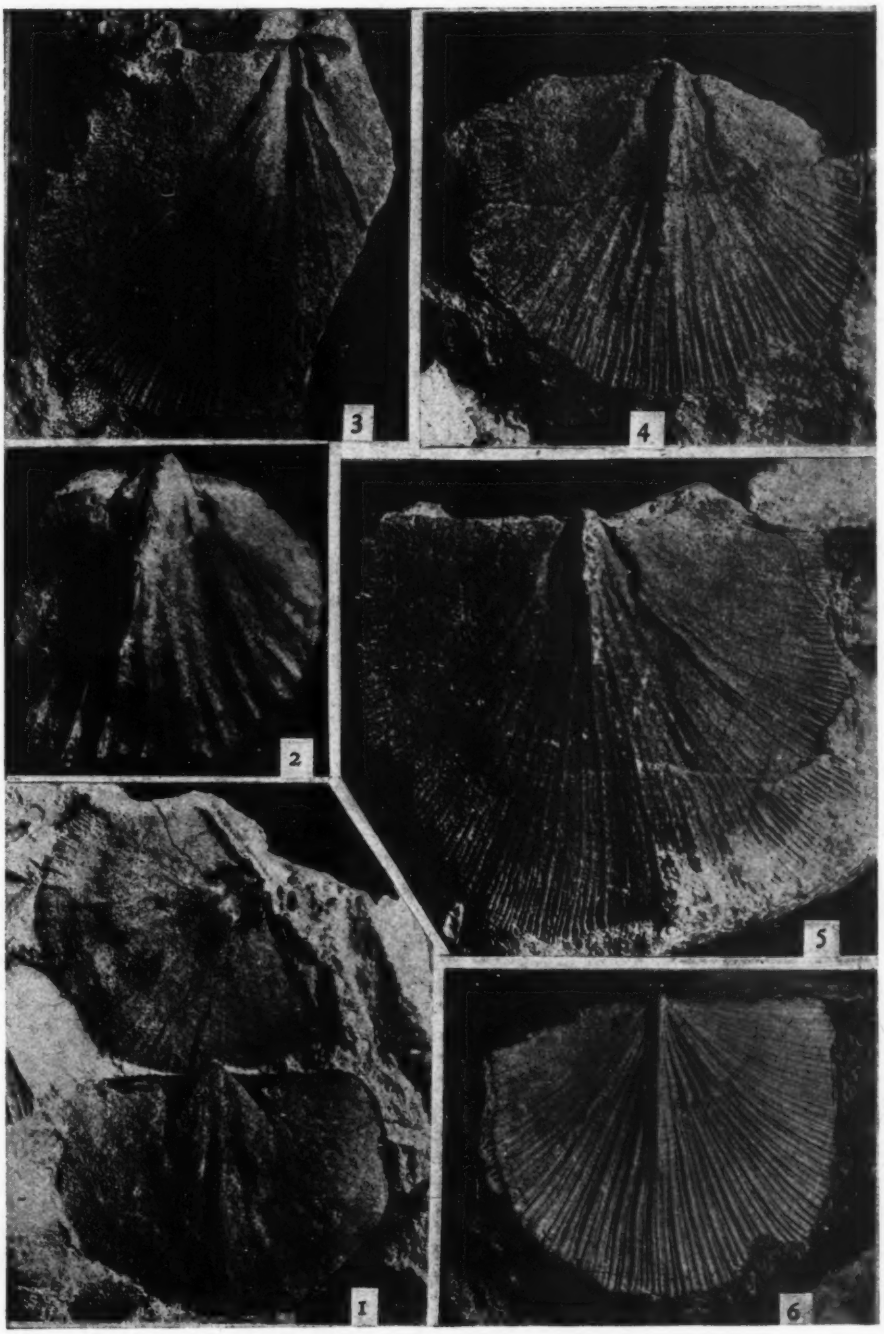
entire length. Thus they approach the type found in *Heterorthis*, the resemblance resulting not from close genetic affinity, but only from the similar form of the valves.

EXPLANATION OF PLATE 34

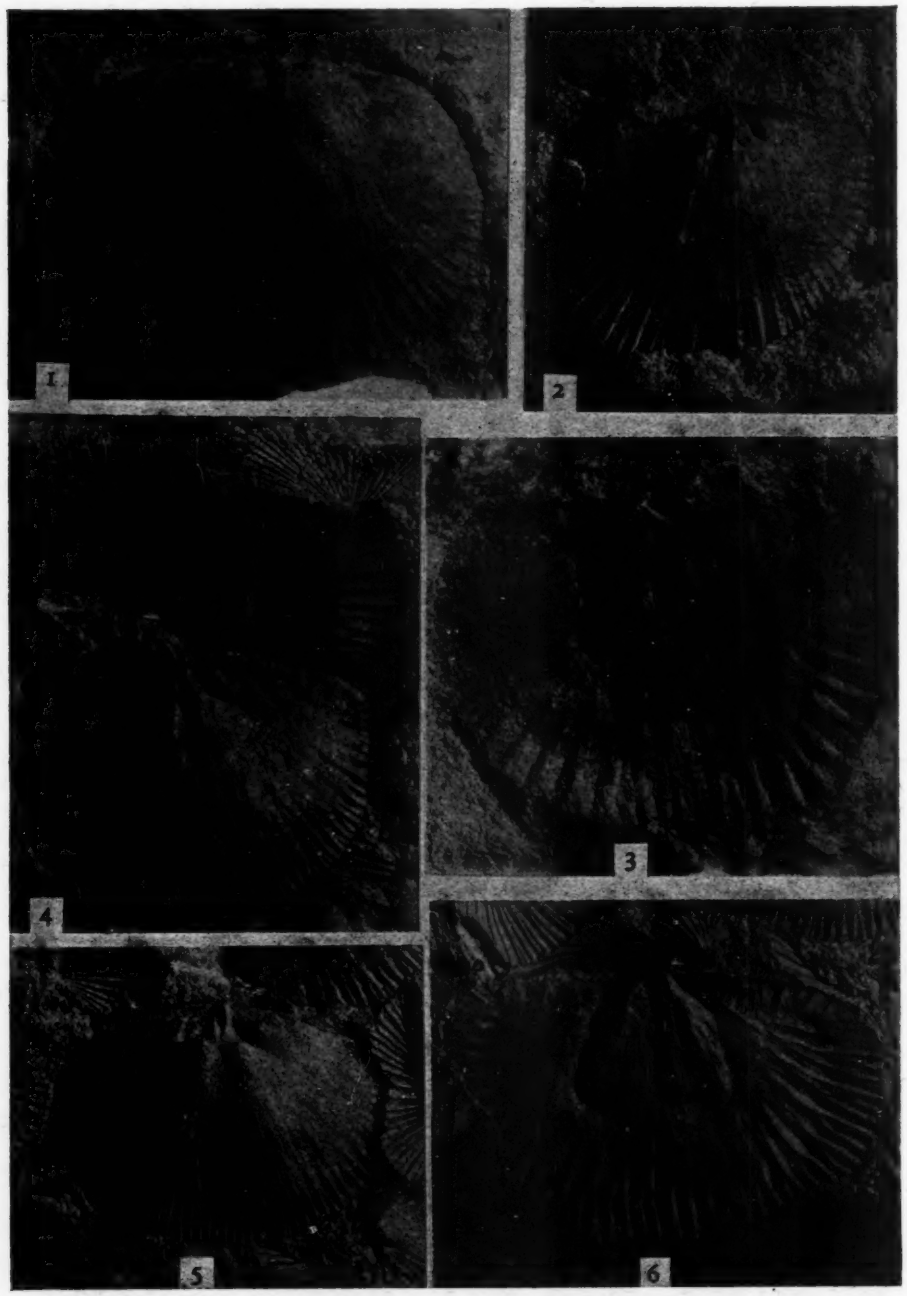
FIGS. *1*—*Harknessella subquadrata* Bancroft. Internal moulds from the *H. subquadrata* zone of the small quarry above Harnage Grange, near Cressage, Shropshire, ×2. (p. 229)

2—*Horderleyella corrugata* Bancroft, n. sp. Internal mould of ventral valve from the type locality above Glenburrell, Horderley, Shropshire, ×2. (p. 237)

3–6—*Smeathenella strophomenoides* Bancroft, n. sp. *3*, Internal mould of dorsal valve from the type locality at Coston (Coston 21a1), ×2; *4*, internal mould of ventral valve from the type locality, ×2; *5*, internal mould of ventral valve of the larger variety from Horderley (Bancroft Coll: V10), ×2; *6*, cast from external mould of ventral valve from type locality at Coston, ×2. (p. 232)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

theatre. They may be compared to the variations that differentiate the large shells of *Harknessella* from the subadjacent horizon.

The following are measurements of two immature stages in a single shell: width at hinge, 12.5 and 16.5 mm.; length 7.5 and 11.0 mm.; ratio, 0.6 and 0.66. The corresponding measurements of two mature valves are: width at hinge, 25.0 and c. 33.0 mm.; length 21.0 and 28.5 mm.; ratio, 0.84 and 0.86.

Type locality and horizon.—In a small exposure in the mound at the entrance to the quarry 500 feet south of Coston farmhouse (Bancroft Coll: Coston 21a). The horizon is in the subzone of *S. strophomenoides* in the *Horderleyella plicata* zone. The Horderley material is from the old quarry in Brokenstones Plantation, opposite the track from the sand pit; it is from the same horizon.

Associated fauna.—Calymene, Wattsella, Horderleyella plicata, Leptaena sp., *Cliftonia andersoni, Glyptorthis.*

Affinities.—The relation of this species to *S. harnagensis* are obscure. *S. harnagensis* is a more transverse form with deeper valves and the characteristic surface foldings on the dorsal. The ventral valve, however, is nearly flat, and differs from that in *S. strophomenoides* mainly in the presence of a narrow, persistent, mesial fold. The ribbing in *S. harnagensis* is also distinctive, consisting of relatively few strong ribs, and intervening bundles of fine derivatives. The cardinalia are larger and more robust in this species. The following are measurements of two individuals: width, c. 27.5 mm. and 31.5 mm.; length, 18.0 and 22.5 mm.; ratio, 0.65 and 0.71.

Closely related to *S. harnagensis* is the form from Cressage 6d[1] which is also a basal Harnagian horizon. This species is distinguished by the very fine character of its ribbing. It may be regarded as a variety of *S. harnagensis.*

[1] For the location of this horizon vide section in the description of *Harknessella subquadrata.* Evidently there is a break at the base of 6d, the higher Costonian zones being absent.

Genus HORDERLEYELLA Bancroft

Horderlyella BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 12, p. 178.

Genotype *H. plicata* Bancroft.

Shells subequally biconvex; dorsal valve harknesselloid or approaching dalmanelloid, rather shallow to moderately deep; ventral valve harknesselloid or harknesselloid characters feebly developed; anterolateral extremities forming short wings or wings obscure. Ribbing coarse to moderately fine. 2b⁻)2a°:H, 2b⁻1⁻)2a°:L, 2c⁻)2a°:L, 3a⁻1⁻)3a°:M, 3a°1°a°)3a°1⁻:L, 4a⁻1⁻)3b°:H. Cardinal process with small, swollen myophore and narrow shaft, or myophore and shaft more or less completely resorbed into a single body. Crural plates short, with deep crural pits; socket lines widely divergent; presocket lines converging rapidly towards the front or nearly transverse.[2] Dorsal muscle area as in *Harknessella*, the posterior scars forming well-defined pits in the notothyral platform. Ventral muscle area lozenge-shaped or forming a truncated lozenge, never bilobate; adductor and divaricator scars feebly defined. Interiors normally traversed by internal ribbing, the same traversing the muscle areas. Costonian to lower Soudleyan.

Observations.—In all assemblages of this genus we find two types of shell, which are linked by imperceptible gradations. In the first the dorsal valve is quite shallow and, apart from a well-defined mesial sinus, the valve presents a nearly uniform convexity. This type of dorsal valve is scarcely to be distinguished from the dalmanelloid. The corresponding type of ventral valve also ap-

[2] Here I use the term presocket lines in the sense of the line joining the extremities of the presocket lines properly so called. This is the form they would assume if the crural pits were completely filled by deposit. Strictly they are deeply angulated in this genus.

EXPLANATION OF PLATE 35

FIGS. *1–3—Dinorthis robusta* Bancroft, n. sp. *1, 2,* Internal moulds of dorsal valves, ×2; *3,* internal mould of a ventral valve, ×2; all from the type bed at Coston, Southeast Shropshire. (p. 240)

4–6—Dinorthis multiplicata Bancroft, n. sp. Internal moulds of dorsal and ventral valves from the type deposit in the Ty-nant section, east of Glyn Ceiriog, Denbighshire; all ×2. (p. 244)

proaches the dalmanelloid, but the curvature is broken by a sharp mesial angulation: in this type independent mesial and lateral folds are obscure or absent. In the other type the valves resemble those in normal Harknessellinae: here the dorsal valve has more or less conspicuous lateral folds and anterolateral concavities, whilst the ventral valve has an independent mesial fold separated from the broad lateral folds by more or less conspicuous sinuses. These surface characters are interesting because they link the characters of normal Harknessellinae and Dalmanellidae in the individual assemblages, and at the same time afford one of the easiest means of identifying the genus.

Corresponding to the variations in valve form are a series of variations in the type of ribbing. When the dorsal folds are strongly developed the axial sector, III, has freely developed externals as in the normal Harknessellinae; when the folds are weak the ribbing relations approach those in Dalmanellidae. These variations may be exemplified by the relations, 3a^{-1-}(3a° and 3b^{-})3a°.

Horderleyella is readily distinguished from *Harknessella* and *Smeathenella* by its short crural plates and converging presocket lines; it is further distinguished by the absence of the bilobate type of ventral muscle area, and from *Smeathenella* by the very shallow valves in that genus. The later Harknessellinae (*Reuschella*) have the dorsal valve more strongly convex than in *Horderleyella*, and in general the surface foldings are more strongly developed. The ribbing relations, 3a^{-1-})3a°, 3c^{-})3b°1°, 3a°1°a°)3a1^{-} and 4a^{-1-})3b° are also distinctive.

Horderleyella is first known from the middle of the Costonian, where it is represented by a small, coarsely ribbed species (*H. plicata*). Similar small species occur at the base of the Harnagian. The genus is represented by a number of species in the Soudleyan below the *Heterorthis retrorsistria* horizon, some of the forms being of large size. After the *Horderleyella* burst the genus disappears except in the vicinity of isolated shore lines, such as the zone of Chirbury.

The species described in this paper are *H. plicata* and *H. corrugata*.

HORDERLEYELLA PLICATA Bancroft

Plate 31, figures 4–7; plate 32, figures 1–4

Horderleyella plicata BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 5, p. 186, pl. 1, figs. 15–18.

Shell small, only slightly transverse, with gently rounded contour and obscure wings, 20–25 mm. wide. Ribbing coarsely plicate 3a^{-1-}a^{-}, 3a^{-2-}, 3a^{-1}°, 3b^{-1-}, [3b^{-1}°], 3c°, [3b°], 3a°1^{-}, 3a°1°, [3a°1°a°] terminal. 3a^{-1-})3a°:M, 3a^{-1}°)3a^{-1-}a^{-}:L, 3b^{-1}°)3b^{-1-}:L, 3b^{-1}°)3c^{-}:L, 4a^{-1}°)4b^{-}:L. Dorsal cardinalia small, usually with deep crural pits and adductor pits; cardinal process often with distinct myophore and shaft. Dental plates rather strong and divergent. Interiors of valves strongly and coarsely ribbed.

Variation.—This species diverges little from the normal characters of the genus. The general form presents the two limiting types, the *Harknessella*-like shells and the type with feebly developed independent folds being equally conspicuous in the assemblages. As in the other characteristic species these two types are linked by imperceptible gradations. The internal characters present no notable abnormalities. The following are approximate measurements of dorsal valves from the principal localities:

	Width at hinge	Length	Ratio
Horderley V10	22.5 mm.	17.0 mm.	0.75
Horderley V10	25	17.75	0.71
Coston 11	17	15.75	0.9

Horderleyella embraces two varieties, the shells from Horderley being for the most part considerably larger than those from Coston. A similar distinction was observed between the shells of *Smeathenella* from these localities, and is found in most of the elements common to the two assemblages. The Coston form may, therefore, be regarded as a dwarf. Similar dwarfed forms are found at the same horizon in the Cressage District.

Type locality and horizon.—In the old quarry in Broken-stones Plantation, Horderley, opposite the track from the sand pit (Bancroft Coll: V10). The Coston material is from the quarry, 500 feet south of Coston farm-house (Bancroft Coll: Coston 21a). Both horizons are in the subzone of *Smeathenella strophomenoides* in the *Horderleyella plicata* zone.

Associated fauna.—The associates at the Horderley locality include: *Calymene* sp., *Wattsella* small sp., *Dinorthis* aff. *D. flabellulum*, *Smeathenella strophomenoides*, *Rafinesquina* large sp., *Leptaena* sp., *Cliftonia andersoni*. The fauna at Coston 21a is listed in the description of *Smeathenella strophomenoides*.

Affinities.—Shells closely similar to *H. plicata* occur as rare fossils in the basal beds of the Harnagian at Horderley. They are associated with *Smeathenella harnagensis*, *Schizophorella salteri*, and a special Harnagian fauna, and are evidently the lineal descendents of this species. The same line continues into the *Horderleyella* burst in the Soudleyan, where it is represented by the large and very coarsely ribbed *H. corrugata*. This form is described in the following section. The other forms with which I am acquainted are mainly from the same Soudleyan horizon. They include

1, A large and relatively finely ribbed shell from below the Frondderw Ash at Bala. This seems to be referable to the same species as a shell from the same horizon at Horderley. In these forms the ribbing plications are flattened out in the later growth-stages.

2, A similar, but smaller form from above the Cwm-clwyd Ash south of Glyn Ceiriog.

3, A little known form from the ashes above the massive Hagley Ash in the Chirbury District. This has the depressed ribbing plications which characterize the species from Bala and Glyn Ceiriog.

4, A form from above the Massive Whittery Ash of Chirbury.

The ribbing statistics of the later forms are still based upon quite inadequate data, and I note the following discriminating characters in Table X with some reserve.

HORDERLEYELLA CORRUGATA
Bancroft, n. sp.
Plate 31, figure 8; plate 32, figures 5, 6
plate 34, figure 2

Shell large, only slightly transverse, with gently rounded contour and obscure wings, c. 28 mm. wide. Dorsal valve with deep, persistent, angular, mesial sinus, low lateral folds and shallow posterolateral concavities, or the mesial sinus shallow, and the lateral folds and concavities obscure. Ventral valve moderately to weakly convex, usually less so than dorsal, with or without independent mesial and lateral folds and lateral sinuses. Ribbing very coarse, sub-angular and irregular. [3a^{-1}-a^{-}], 3a^{-1}-, [3a^{-2}-], 3a^{-1}°, [3b^{-1}-], [3b^{-1}°], 3c^{-}, 3b°, 3a°1-, 3a°1°, [3a°1°a°] terminal. 3a^{-1}°)3a^{-1}-a^{-}:H2, 4a^{-1}°)4a^{-1}-:L2-M. Cardinal process with myophore and shaft resorbed into a single body, the same nearly filling the entire space between crural plates. Crural pits very fine or absent at maturity. Ventral muscle area usually deeply impressed, forming a truncated lozenge or approaching subtrigonal; adductor and divaricator scars separate, the former consisting of a narrow posterior trunk and a wide anterior depression. Dental plates robust. Interiors of valves traversed by internal ribbing, or same restricted to peripheral zone.

Variation.—Apart from those noticed in the diagnosis the most important variations are

1, A rather rare transverse form: the following are measurements of an example of this type and two normal individuals: width of valve, 31.0, c. 28.5, and 28.0 mm.; length of dorsal valve, 19.5, 23.5, and 22.0 mm.; ratio, 0.63, 0.82, and 0.78.

2, The dental sockets may contain two separate fossae. They may be bounded at their extremities by a ridge in line with the

TABLE X

	3a^{-1}°)3a^{-1}-a^{-}	3b°1°)3b^{-1}-	3b^{-1}°)3c^{-}	4a^{-1}°)4a^{-1}-	4a^{-1}°)4b^{-}
Horderleyella plicata	L	L	L	L1	L
H. corrugata	H			L2–M	L–M
H. sp., Glyn Ceiriog	[M–H]	[M–H]	H	[H]	[H]

convergent presocket lines, and posteriorly by a small triangular callosity. The internal moulds of such shells have a very characteristic appearance, the presocket lines appearing to be produced backwards to near the hinge.

3, Certain individuals exhibit a pair of callosities in the anterolateral angles of the notothyral platform as in the genus *Reuschella*.

4, The dorsal muscle area is usually represented by a pair of narrowly triangular scars defined by peripheral ridges; more rarely the scars are subovate or indefinite.

5, In immature shells the ventral muscle area may be lozenge-shaped. In mature individuals the lozenge is usually truncated in front of the lateral angles, so that the form approximates to subtrigonal. The subtrigonal form is found in narrow, strongly convex muscle-areas.

Type locality and horizon.—In a small exposure by the cartway above the house at Glenburrell, Horderley, nearly due north of the 'G' in 'Glenburrell' on the 6-inch Ordnance Survey map, and a few paces east of the gate. The shell occurs in greenish, yellow-weathering sandy mudstones and calcareous shell bands of the Glenburrell beds. The horizon is in the *Horderleyella* beds of the Soudleyan.

Associated fauna.—*Tetradella*, *Bröggerolithus* sp., *Calymene*, *Proetus*, *Pholidops*, dalmanelloids, *Rafinesquina*, *Leptaena*, a large leptaenoid, *Cliftonia* aff. *C. spiriferoides*.

Affinities.—The form from the summit of the Glyn Gower occurs at a somewhat lower horizon and has the ribbing finer and more even than in *H. corrugata*. The same holds true for the species from Glyn Ceiriog and the forms from above the Hagley Ash at Chirbury. As far as I may judge from the ribbing statistics these species are intermediate between *H. plicata* and *Reuschella*, and they may be ancestral to the latter genus.

Genus REUSCHELLA Bancroft

Reuschella BANCROFT, 1928, Manchester Lit. Philos. Soc. Mem., vol. 72, no. 12, p. 180.

Genotype, *R. semiglobata* Bancroft.

Shells large, harknesselloid, unequally biconvex or concavo-convex; posterolateral angles produced as small wings. Dorsal valve with mesial sinus and independent lateral folds, or approaching semiglobose. Ventral valve with independent mesial fold, with or without lateral folds and sinuses. Ribbing usually fine or moderately fine. 2b⁻)2a°:H, 2a⁻1⁻)2a°:H, 3a°1°a°)3a°1⁻:H, 4a⁻1⁻)3b°:L, 4a⁻1°)4a⁻1⁻:M–H, 4a⁻1°)4b⁻:M—H. Cardinal process subovoid; crural plates with anteriorly convergent presocket lines; crural pits fine and small or absent. Adductor pits usually well developed. Ventral, muscle area lozenge-shaped or forming truncated lozenge, more rarely bilobate; adductor and divaricator scars separate.

Observations.—The earliest representatives of *Reuschella* are difficult to separate from the latest representatives of the ancestral *Horderleyella*. The transition phase belongs to the *Heterorthis retrorsistria* burst during which the distinctive *Horderleyella* types are eliminated. Above this horizon *Reuschella* is distinguished from *Horderleyella* by its characteristic ribbing relations and by the presence as a general character of an independent mesial fold on the ventral valve. Apart from these distinctions *Reuschella* presents a number of shell forms which are never found in the ancestral genus. In many species the dorsal valve is semiglobose and the ventral valve very shallow or concave; in others the surface folds and sinuses attain to an extravagant development.

In immature shells the cardinalia present the *Horderleyella* type, the adductor pits and crural pits forming deep cavities corresponding to the acicular fillings in internal moulds. Mature individuals may be distinguished from *Horderleyella* by the fine character of the crural pits or by their absence. In some of the later forms, and among these we must include the genotype, the ventral muscle area is flattened and bilobate, and the lateral margins in front of the dental plates are nearly parallel. In these respects and also (though more rarely) in the character of the crural plates such forms approach *Harknessella*. They may be distinguished from that genus by reference to the crural plates in young shells, which are of the *Reuschella* type, and by the preponderance of the latter type in mature assemblages.

Reuschella embraces two groups, the *R. bilobata* group and the *R. horderleyensis*

group. The former may be described as follows:

Diagnosis of the R. bilobata group.—Shell subrectangular or subquadrate. Dorsal valve strongly convex, sinuate or semiglobose. Ventral valve shallow or concave, with independent lateral folds and sinuses. 2a^{-1}-)2a°:H, 2b^{-1}-)2a°:L, 2c-)2a°:L, 3a°1°a°)3a°1^{-}:H, 4a^{-1}-)3b°:L. Ventral muscle area forming a truncated lozenge or bilobate.

This group appears first in the *Heterorthis retrorsistria* burst in the Soudleyan, where it is associated with *Heterorthis retrorsistria*, *Sowerbyella sericea* and *Howellites*. It is associated with the same groups of species in the *Kjaerina bipartita* zone, and in the Actonian it occurs with the *Onniella* fauna.

Diagnosis of the R. horderleyensis group, Reuschella horderleyensis, s.l. (*Bancroft, 1928, p. 187, pl. 2, figs. 6–8.*—Shell transverse to subquadrate; lateral margins usually convergent. Dorsal valve moderately convex, with deep mesial sinus and independent lateral folds. Ventral valve rather deep with strongly carinate mesial fold; lateral sinuses obscure or absent. Ribbing fine and even. 2a^{-1}-)2a°:H, 2b^{-1}-)2a°:H, 2c-)2a°:H, 3a°1°a°)3a°1^{-}:M–H, 4a^{-1}-)3b°:L. Ventral muscle area lozenge-shaped or forming a truncated lozenge.

The broadly conceived *R. horderleyensis* is restricted to a zone in the upper Soudleyan at which horizon it is widely distributed in north Wales and Shropshire. Except in the more westerly localities it is accompanied by *Soudleyella* and *Sowerbyella soudleyensis;* whilst *Bröggerolithus soudleyensis* and *Dinorthis* sp. seem to be invariable associates.

Apart from the ribbing relations the most distinctive characters are the association of a rather high, strongly carinate ventral valve with a moderately convex, deeply sinuate dorsal. For the distinctive ribbing characters the reader is referred to the table of genera.

Subfamily HETERORTHINAE Schuchert and Cooper, 1932

HETERORTHIS RETRORSISTRIA (M'Coy)

Orthis retrorsistria McCoy, 1852, British Paleozoic fossils, p. 224, pl. iH, figs. 12, 13, 1852.

This species marks an important horizon in the lower Soudleyan, and on that account was included in my original list of indices. Its retention as a zone fossil is undesirable owing to the presence of a closely similar form in the Costonian, and pending the detailed study of these forms it can be allowed no higher value than that of a burst fossil.

The types of *H. retrorsistria*[1] are small and much distorted, and none exhibits the salient characters of the species. Closely similar forms occur in the highly cleaved rocks of Bala; but where the fossils are unaltered by compression the form exhibited in the type specimens is not represented in the assemblages. That form, and here I refer especially to the ventral muscle area, is a consequence of distortion.

The true characters of the species are exhibited in Davidson's figures of the shells from Ketch and Pentre Llymru, Llanfyllin, which he refers to *O. alternata*, and particularly in plate 31, figure 6. The same author figures quite satisfactory examples from Cerrig-y-Druidion in his Silurian supplement (pl. 14, figs. 7, 14).

The most important discriminating character is the ventral muscle area. In this the divaricator scars are long and narrow, and the external lateral margins are nearly straight or exhibit a more or less decided concavity. Both types are represented in the same assemblages and contrast strongly with the broad scars and convex lateral margins in the Longvillian and Marshbrookian species (*H. alternata*). The other distinctive features are the relatively small size of the shells and the convexity of the dorsal valve. In the later species the dorsal valve is nearly flat. The pronounced retroflexion of the ribbing to which the species owes its name does not seem to be a normal character. In most of my specimens this feature is certainly not more conspicuous than in *H. alternata*.

H. retrorsistria embraces a number of varieties which seem to characterize distinct horizons in the Soudleyan. For the most part these appear to have the dorsal valve faintly concave or nearly flat, but the extent to which this is due to compression has not

[1] "This species is said to occur in great profusion in the Caradoc or Bala flags of the south end of Pen-y-Gaer, near Cerrig-y-Druidion," Davidson, Sil. Mon. p. 266.

been ascertained. The form in which the valve is unusually deep is associated with valves of feeble convexity in the *Heterorthis* burst.

The position of the *Retrorsistria* burst is about 50–100 feet above the Frondderw ash; it is a well marked horizon in north Wales, occurring at Meifod, Glyn Ceiriog, Bala and at many other localities. The type specimens were evidently from this horizon.

The associates of *H. retrorsistria* include *Howellites*, *Reuschella* aff. *R. bilobata* and the large *Sowerbyella sericea*. The same fossils occur with *H. alternata* in the lower Longvillian, so that it is most probable that the latter is derived directly from *H. retrorsistria*. This result is important because it sets an approximate limit to the appearance of the *H. alternata* type in all sections, and assists in working out interregional correlations.

Superfamily ORTHACEA Walcott and Schuchert, 1908

Paleontological Methods

The rib system.—The primaries of the rib-system in Orthacea have not yet been correlated with those in Dalmanellacea, so that we are compelled to devise a modification of the notation. The method which I adopt consists in treating all *apparent* primaries as true primaries, and modifying the initial symbol with the mark ′. Thus the first, second and third ribs arising at the umbo are denoted by the symbols, 1′, 2′ and 3′, and their derivatives by 1′a⁻, 1′a⁻1⁻, 3′a⁻1⁻a⁻ etc. This system has the advantage of universality of application, but the symbols have no phylogenetic significance outside restricted groups.

In some forms, and notably amongst the Dinorthidae, the relations of the derivatives on the dorsal valve are obscure, the *apparent secondaries* and *tertiaries* appearing to arise by intercalation between the *apparent primaries*. On the ventral valve, however, the corresponding sinuses, and hence the ribs also, appear as branches. In this case we may deduce the relations of the dorsal rib system from those of the ventral valve; but it is more practicable to work on the ribbing of the latter. The median *apparent primary* of the ventral valve is denoted by 1′. The other *apparent primaries* are denoted by 2′, 3′, 4′ etc.

Family DINORTHIDAE

Genus DINORTHIS Hall and Clarke

Dinorthis HALL and CLARKE, 1892, New York Geol. Survey Paleontology, vol. 8, pt. 1, pp. 195, 222.

This genus embraces five subgenera of which *Plaesyomys* Hall and Clarke is certainly polyphyletic, and therefore unsound in its present constitution. *Plaesiomys* embraces the more finely ribbed species with the general form and internal characters of *Dinorthis*, s. s.; it includes, therefore, both the forms described in this paper.

DINORTHIS (PLAESIOMYS) ROBUSTA Bancroft, n. sp.

Plate 35, figures 1–3; plate 36, figures 4, 5

Shell large, transverse to subcircular, about 30 mm. wide. Dorsal valve with or without faint, impersistent mesial sinus; ventral valve concave, asinuate, sometimes with an obscure mesial fold. Ribbing moderately fine, consisting of 18–22 apparent primaries, and two or three apparent secondaries and tertiaries in each sector; first apparent secondaries (x′a⁻ and x′a°) appearing close to hinge; second apparent secondaries (x′b⁻, x′b°) and apparent tertiaries appearing in half-grown stage and

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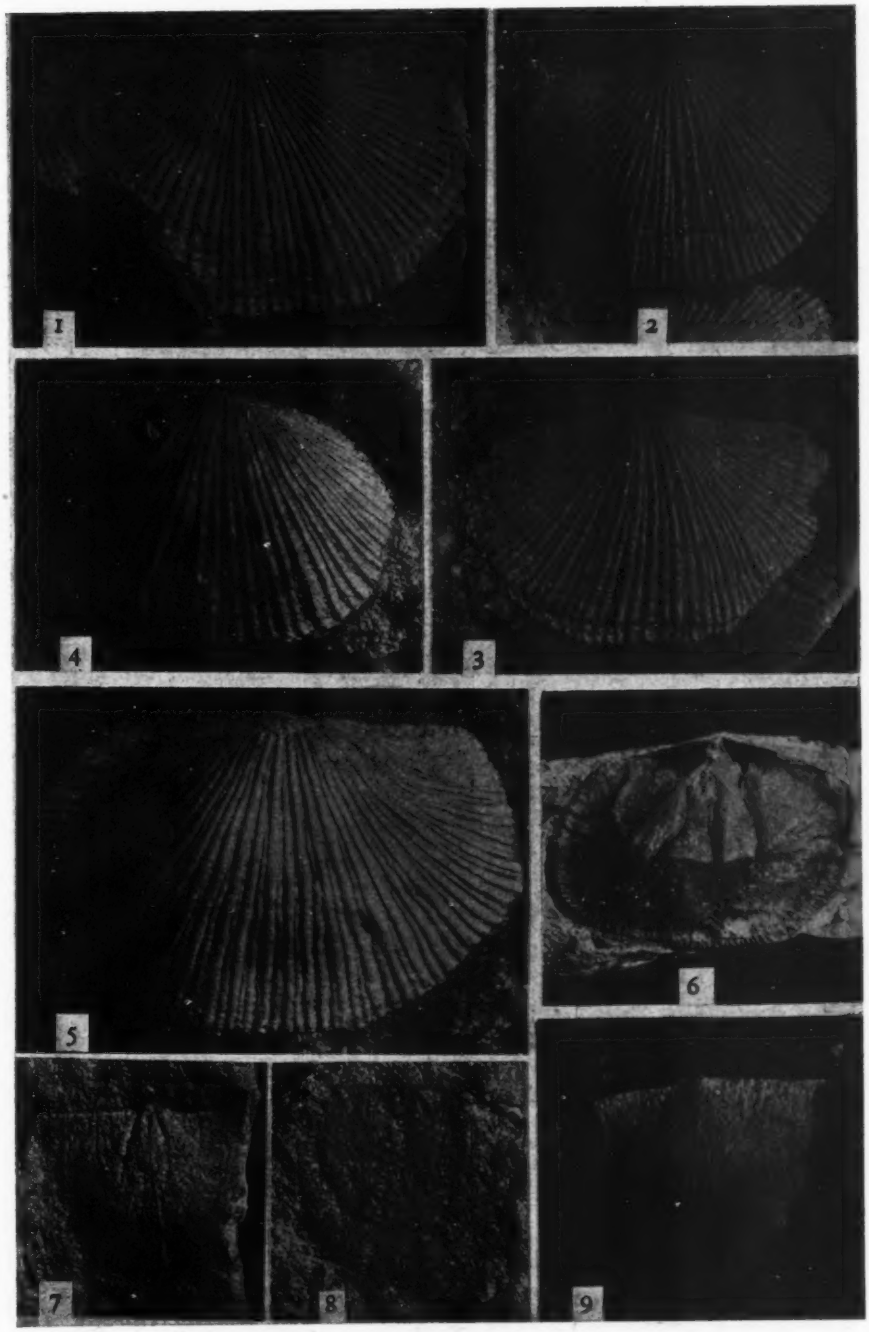
EXPLANATION OF PLATE 36

FIGS. *1–3—Dinorthis multiplicata* Bancroft, n. sp. *1*, Cast from external mould of ventral valve ×2; *2*, *3*, casts from external moulds of dorsal valves, ×2. All from the type deposit in the Ty-nant section, east of Glyn Ceiriog, Denbighshire. (p. 244)

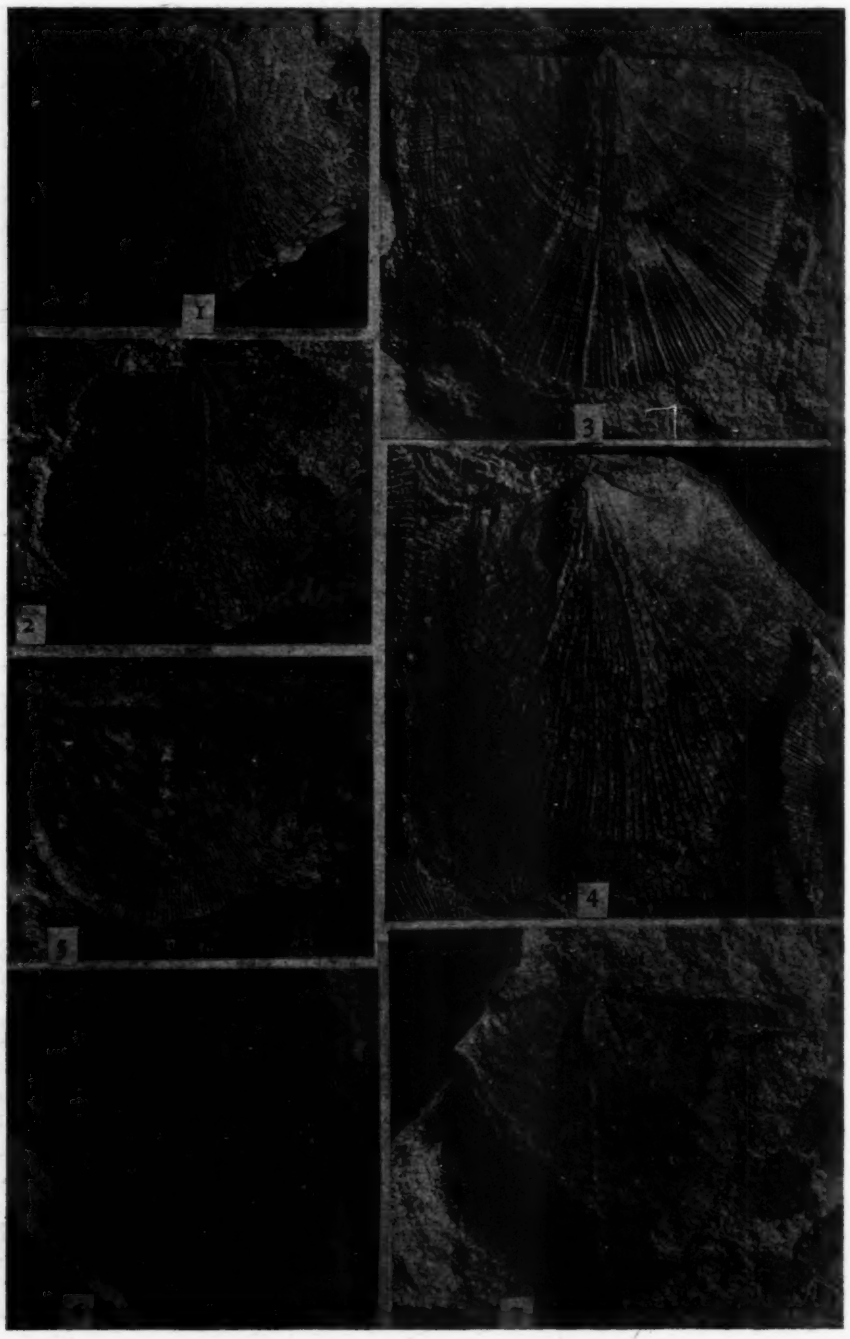
4, *5—Dinorthis robusta* Bancroft, n. sp. Casts from external moulds of dorsal valves from the type locality, ×2. (p. 240)

6—Heterorthis retrorsistria M'Coy. Internal mould of ventral valve from Cerrig-y-Gath, south of Bala, Merioneth, ×2. The divaricator scars in this specimen approximate to the type found in *H. alternata*, but are much narrower. (p. 205)

7–9—Kjaerina hedstroemi Bancroft. *7*, Internal mould of ventral valve, ×2; *8*, internal mould of dorsal valve, ×2; *9*, cast from external mould of ventral valve, ×2; all from the type bed at the summit of Rookery Wood, Horderley, Southeast Shropshire. (p. 247)



Bancroft, Ordovician Brachiopods



Bancroft, Ordovician Brachiopods

between middle of shell and periphery; [x′a⁻1⁻], [x′b⁻], [x′b°], [x′a°], [x′a°1°] terminal; about 90 ribs terminating at periphery. Secondary and tertiary ribs on dorsal valve apparently intercalated. Cardinal process robust, with distinct myophore and shaft; myophore fissured and crenulate. Bases of attachment of crural plates steeply inclined, nearly vertical at maturity. Mesial ridge very short, low. Dorsal muscle area usually distinct; posterior scars large, broadly rounded posteriorly, not produced between crural plates at maturity; anterior scars very small or obscure, often separated from posterior scars by oblique ridge. Ventral muscle area variable, normally subrectangular, sharply defined by peripheral ridge; adductor tract indefinite; divaricator scars frequently bilobate. Vascular sinuses often strongly developed in both valves. Ventral interior with a pronounced marginal frill.

Material and variation.—The material consists of natural moulds lying higgledy-piggledy in a poorly cemented grit, and has suffered in varying degrees from contemporaneous crushing and subsequent loading pressures. As there is little evidence of tangential pressures in the immediate vicinity it must be presumed that the variation in contour, in so far as it is not an original character, is due to loading. How considerable this variation is will appear from the appended measurements:

Width	Length of dorsal valve	Ratio
26.0 mm.	24.5 mm.	0.81
30.5	25.0	0.82
31.5	21.5	0.68
c. 34	30.5	0.9
36.0	24.0	0.66
37.0	33.0	0.89

The ribbing does not exhibit important variations in its general characters. It may be exemplified by the following somewhat immature example of a ventral valve:

Left side	Right side
1′a°	1′ 1′a°
2′, 2′a°, 2′a°1°, 2′b°	2′, 2′b°, 2′a°, 2′a°1°
3′, 3′a°, 3′a⁻, 3′a°1⁻	3′, 3′a⁻, 3′a°
4′, 4′a⁻, 4′a⁻1⁻, 4′b⁻, 4′a°	4′, 4′a⁻, 4′b⁻
5′, 5′a⁻1⁻, 5′a⁻, 5′b⁻	5′, 5′a⁻1⁻, 5′b⁻
6′, 6′a⁻1⁻, 6′a⁻, 6′b⁻, 6′a°	6′, 6′a⁻, 6′a⁻1°, 6′b⁻
7′, 7′a⁻, 7′a°	7′, 7′a⁻, 7′b⁻
8′, 8′a⁻	8′, 8′a⁻
9′, 9′a°	9′

Our figured specimen of the ventral valve is somewhat abnormal, the muscle area exhibiting unusually well defined adjustor scars, strongly bilobate divaricators, and a rather distinct lateral concavity. In the normal type the sides are nearly straight, the adjustors feebly differentiated, and the divaricator lobes short or absent. In some shells the muscle area is extended anteriorly in front of an earlier strongly defined boundary line. This gives rise to a narrow, elongated impression extending through some two-thirds of the length of the shell, and traversed by a strongly defined transverse ridge (the earlier anterior margin). The ridges defining the anterior extension are quite fine, and the extension itself is often an obscure feature.[1]

The marginal frill in this species consists of a series of coarse, rather irregular plications, frequently bifurcating, and bearing an intimate relation to the ribbing and vascular sinuses. The frill may extend almost to the

[1] I have observed the same greatly elongated type of muscle area in the form from Brokenstones Quarry, Horderley. This is a coarsely ribbed species.

EXPLANATION OF PLATE 37

FIGS. *1, 2*—*Kjaerina hedstroemi* Bancroft. Internal moulds of ventral valves ×2; both from the type bed at the summit of Rookery Wood, Horderley, Shropshire. (p. 247)

3, 4—*Kjaerina bipartita* (Salter). Internal moulds of ventral valves, ×2. *3* is from a low exposure in the southeast angle of the field north of the old quarry by the lane from Cheney Longville to the Common, in the Horderley District; *4*, from the exposure in the bank of the lane from Cheney Longville to the Common, 470–480 ft. east of the old quarry by the south side of the lane. The characteristic cardinalia of the dorsal valve are exhibited in the bottom left-hand corner of fig. *4*. (p. 248)

5–7—*Kjaerina geniculata* Bancroft. *5*, *6*, From 12 yards east of the type locality; *7*, internal mould of ventral valve from the type locality in the lane leading west from Cheney Longville; all ×2. Fig. *6* shows the final stage in the development of an abruptly geniculate ventral valve; the shell is from a slightly higher horizon than that in fig. *7*. (p. 249)

muscle area, but usually it is strongly defined only in the peripheral zone. The peripheral zone in the dorsal valve exhibits the usual fine internal ribbing; except in gerontic shells this ribbing may extend far into the interior.

Type locality and horizon.—In the cart track, 440 feet east of the farmhouse at Coston, Shropshire, and due south of 'Q' in 'Old Quarry' on the 6-inch Ordnance Survey map. In the subzone of *Dinorthis robusta* (*Horderleyella plicata* zone).

Associated fauna.—*Marrolithus, Calymene, Wattsella* small sp., *Horderleyella plicata, Smeathenella* sp.

Affinities.—Several species of *Dinorthis* have been described from the Costonian of East Shropshire and Girvan, but with the exception of our fossil all these are coarsely ribbed shells, and for the most part exhibit simple, unbranched primaries. Reed (1917, pl. 7, figs. 2–6), however, has figured coarsely ribbed shells from the Stinchar limestone and Balclatchie group in which the ribs branch at quite early growth stages. A much closer form to *D. robusta* is *D. multiplicata* from the summit of the Soudleyan. These species are compared in the next section. They both differ from the finely ribbed post-Marshbrookian species in having a coarse marginal frill in the interior of the ventral valve.

Dinorthis (Plaesiomys) multiplicata Bancroft, n. sp.

Plate 35, figures 4–6; plate 36, figures 1–3

Shell transversely subrectangular to semioval, c. 32 mm. wide. Dorsal valve without mesial sinus; ventral valve feebly concave, sometimes with obscure, impersistent mesial fold. Ribbing consisting of 20–26 apparent primaries, and 2–5 apparent secondaries and tertiaries in each sector; first apparent secondaries appearing near hinge; c. 80–100 ribs terminating at periphery of dorsal valve; secondary and tertiary ribs in dorsal valve apparently intercalated. Cardinal process simple, ovoid, usually slender, supported on flattened notothyral platform. Crural plates slender, with moderately inclined to nearly horizontal bases of attachment. Dorsal muscle area distinct and quadripartite, or indistinct; posterior scars (when defined) large, angulated posteriorly. Ventral muscle area large, subquadrate to subtriangular, extending through half, or rather less than half the length of the shell; anterior margin straight or with shallow reentrant angle. Ventral interior with a sharply incised marginal frill; a comparable, but much finer frill sometimes present in dorsal valve.

Variation.—In this species the hinge is always wide, and the greatest width is measured in front of the hinge-line. The following are characteristic measurements:

Locality	Width of valve	Length of valve	Ratio
Glyn 18d	19.0 mm.	11.0 mm.	0.58
Glyn 18d	24.5	17.5	0.71
Glyn 18d	31.0	20.0	0.64
Glyn 18d	31.5	18.5	0.59
Glyn 18d	34.0	24.0	0.7
P12	31.5	22.5	0.71

The following is a list of the ribs observable in the figured specimen of the ventral valve:

Left side		Right side
1′a°	1′	1′a°
2′, 2′a°, 2′b°		2′, 2′b°, 2′a°
3′, 3′a°		3′, 3′a⁻, 3′a°
4′, 4′a° . . .		4′, 4′a⁻, 4′a°
5′, 5′a⁻, 5′b⁻		5′, 5′a⁻, 5′b⁻
6′, 6′a⁻		6′, 6′a⁻
7′, 7′a⁻, 7′b⁻ . . .		7′, 7′a⁻, 7′b⁻
8′, 8′a⁻, 8′b⁻		8′, 8′a⁻
9′, 9′a⁻, 9′a°		9′, 9′a⁻, 9′b⁻
10′, 10′a⁻, 10′b⁻		10′, 10′a⁻, 10′b⁻
11′, 11′a⁻, 11′a°		11′, 11′a⁻
12′, 12′a⁻		12′, 12′a⁻
13′		13′, 13′a⁻, 13′a°
		14′

In this specimen it is doubtful whether 6′ and 7′ on the right side should not be regarded as a single apparent primary.

The variety of this species from Horderley sometimes exhibits strongly bilobate muscle scars in the ventral valve—a type which is not known in the other localities. The Meifod variety is characterized by rather strongly convex dorsal valves, by the rounded posterior margins of the dorsal adductor scars and by the rather steep inclination of the bases of attachment of the crural plates. These characters are usually associated with phylogerontic assemblages and may indicate that the Meifod shells are from a slightly higher horizon than those from Horderley and Glyn Ceiriog.

The marginal frill in the ventral valve exhibits no marked variation in the different

assemblages. It is restricted to a broad and well-defined band which in mature shells never extends as far as the muscle area. The corresponding zone in the dorsal valve is traversed by internal ribbing, which in some individuals assumes the sharply incised but rather sinuous character of the ventral frill.

Type locality and horizon.—In the stream section south of Ty-nant, east of Glyn Ceiriog. The type band enters the bed of the stream c. 35 yards south of Ty-nant (Bancroft Coll: Glyn 18d). The horizon is in the zone of *Dinorthis multiplicata* at the summit of the Soudleyan. The Horderley specimens are from the base of the section in the small quarry by the west side of Rookery Wood (Bancroft Coll: P12), and are from the same horizon.

Associated fauna and distribution.—At Glyn Ceiriog this species occurs in the greatest profusion in association with only occasional specimens of *Rafinesquina expansa* and *Wattsella* aff. *W. horderleyensis*. The same assemblage is found at Horderley and other localities in East Shropshire, but there the large *Rafinesquina* is more abundant. At Meifod the most conspicuous fossils are *Rafinesquina* and coarsely ribbed varieties of *Wattsella horderleyensis*.

Affinities.—Both in the character of the ribbing and the presence of a coarse marginal frill this species bears a close resemblance to *D. robusta*. The principal distinguishing characters are: 1, *D. multiplicata* is a more consistently transverse, and a somewhat more finely ribbed form than *D. robusta*. 2, The notothyral platform and the bases of attachment of the crural plates are less steeply inclined in *D. multiplicata*. 3, The notothyral platform is nearly flat in *D. multiplicata*, and is relatively larger when compared with the cardinal process. In *D. robusta* the notothyral platform and cardinal process approach more nearly to the type normal to the *D. flabellulum* group. 4, In normal varieties of *D. multiplicata* the posterior margin of the dorsal muscle area is angulated, whereas in *D. robusta* it is broad and rounded.

The post-Marshbrookian dinorthides fall into two well-marked morphological groups of which one embraces the coarsely ribbed shells (like *D. flabellulum*), and the other more finely ribbed shells (*D. porcata* group). The *D. porcata* group, as represented by the known species, are distinguished from *D. multiplicata* by their longer form and by the absence of coarse marginal frills in the ventral valve, and individually by differences in the muscle areas and ribbing. *D. grandis*, Portlock (1843, pl. 32, fig. 25) from Tyrone is interesting on account of the smooth interiors of the shells. The form from the Drummuck group, referred by Reed (1917, pl. 7, figs. 7–12) to *D. porcata* is notable for its concentrated type of ventral muscle area, a character it shares with the other Girvan dinorthides as well as many other genera from that area.

Superfamily STROPHOMENACEA Schuchert
Family STROPHOMENIDAE King
Subfamily RAFINESQUININAE Schuchert
Genus KJAERINA Bancroft

Kjaerina BANCROFT, 1929, Manchester Lit. Philos. Soc. Mem., vol. 73, no. 4, p. 43.

Genotype, *K. typa* Bancroft.

Shell small, rafinesquinoid, parabolic or subtrigonal; anterolateral angles produced as wings. Ventral valve convex, semigeniculate or geniculate. Dorsal valve flat. Ribbing of ventral valve consisting of several alternating series of weaker and stronger ribs; one or more conspicuously strong ribs in a narrow mesial sector. Ribbing of dorsal valve fine. Dental plates diverging at 30°–90°. Ventral muscle area shallow and feebly differentiated, bounded at the sides by a pair of fine, subparallel ridges (when the dental plates diverge more widely) or by a pair of narrowly divergent, composite plates (dental plates+lateral boundary ridges of muscle area), or lateral boundary indefinite; anterior boundary always indefinite; posterior region of muscle area with a simple mesial ridge. Interior of dorsal valve as in *Rafinesquina*, with anchor-shaped platform, mesial ridge, and simple, paired, platelike apophyses. Interiors of both valves clearly reproducing external ornament.

Variation.—Apart from the quite remarkable diversity of valve form the most important variations are found in the composite plates at the side of the ventral muscle area. The predominant types, which are intimately related to one another, and form a continuous series, are as follows:

1, In the early forms the dental plates

consist of a pair of slender laminæ diverging at about 90°. The ventral muscle area is without a definite boundary in front of these laminæ, or the lateral margins may be defined by a pair of fine, subparallel ridges.

2, The dental plates are narrowly divergent; their anterior extremities are fused with the laminæ at the sides of the muscle area forming a pair of narrowly divergent plates.

3, The dental plates are long and narrowly divergent, and unite with a pair of short boundary ridges at their anterior extremities.

It will be noted that in all except the most rudimentary types the lateral extension of the muscle area is restricted either by narrowly divergent dental plates or by accessory subparallel ridges.

Relation of Kjaerina to Rafinesquina.—The earliest species of *Kjaerina* have the characters of immature *Rafinesquina*, and apart from the invariable presence of a conspicuous mesial rib no character serves to distinguish between them. It may be inferred, therefore, that *Kjaerina* is derived in *Rafinesquina*. The later species of *Kjaerina*, and here I include the bulk of the species, are distinguished from *Rafinesquina* by the ollowing association of characters:

1, The smaller size of *Kjaerina* and the more delicate cardinalia in that genus. These distinctions are evident when the two genera are associated in the same deposit. It is true of all but dwarfed species of *Rafinesquina* living in unfavourable habitats, and certain abnormal groups which might be removed from that genus.

2, The presence of a strongly defined mesial rib on the ventral valve of *Kjaerina*.

3, The ventral muscle area in *Rafinesquina* is large and flabellate. In *Kjaerina* it is never flabellate; either it is indefinite or its lateral development is restricted by narrowly divergent dental plates or special subparallel boundary ridges. Further, in *Rafinesquina* the ventral muscle area is traversed by radiating ridges, which serve to define the anterior margin. These features are absent in *Kjaerina*.

4, In normal *Rafinesquina* the dorsal muscle area is more or less deeply impressed, and is traversed by strong radial ridges; these features are not found in *Kjaerina*.

5, Thick-shelled forms with smooth interiors and vascular sinuses are never found in *Kjaerina:* the interiors of the valves are always finely ribbed in that genus.

These distinctions might be greatly amplified if we compared *Kjaerina* with the individual subgenera of *Rafinesquina*.

The separation of *Kjaerina* from *Rafinesquina* depends upon the existence of the distinguishing characteristics which I have set out above: the separation is justified by the fact that the genus is constituted by a large and diversified group of species occupying a definite section of the time scale and intimately related to one another by their variations. It is a natural group and is shown to be so by its geological history.

Geological history of Kjaerina.—Our first species of *Kjaerina* are from a high horizon in the zone of *Reuschella horderleyensis* in the Soudleyan. At this horizon the shells are small plano-convex forms with rather widely divergent dental plates. They are rudimentary structurally and may be regarded as the iceloplasmic ancestors of all the later forms. Similar but somewhat larger shells (*K. jonesi minor*) occur in the basal beds of the lower Longvillian and in the succeeding horizon of the *W. horderleyensis* zone (*K. jonesi*), where the shells show a further increase in size. The same type occurs in the zones of *Wattsella indica* and *Raymondella typa*. At the latter horizon appear the forms with rather shallow ventral valves (*K. richteri*), a type which appears in great force in the basal zone of the upper Longvillian, where the genus attains its greatest dimensions (*K. bipartita*). The series leading from *K. jonesi* to *K. bipartita* lies along a trend characterized by widely divergent dental plates and a progressive increase in size. Closely linked to this stock by intermediate types in the *W. horderleyensis* and *Kjaerina hedstroemi* zones is the group with narrowly divergent dental plates. This type arises partly from a decrease in the angle between the dental plates and partly from the strengthening of the boundary ridges at the sides of the muscle area. All the forms to which I now refer present this kind of composite laminæ. *Kjaerina hedstroemi* from the middle of the lower Longvillian has a plano-convex shell like the earlier forms. Similar shells but with strong wrinkles

on the posterior part of the shell appear in the middle part of the upper Longvillian (*K. typa*), and continue to the end of that stage; at the same time appear the first forms with quasigeniculate ventral valves, from which arises the line culminating in the geniculate shells of the *K. geniculata* zone (*K. geniculata*). The first representatives of this line occur as variations of normally plano-convex species in the zone of *Raymondella robusta;* they are large shells with a narrow and rather obscurely deflected border.

TABLE XI

Horizon	Species of *Kjaerina*	East Shropshire	Welsh Borders	Central N. Wales	West N. Wales
U. Soudleyan	sp.	rare	(absent)	(absent)	(absent)
W. horderleyensis—*Kjaerina*	*jonesi intermedia*	common	fairly common	(absent)	(absent)
K. hedstroemi	*hedstroemi*	v. common	common	(absent)	(absent)
W. indica *R. typa*	aff. *jonesi richteri*	v. common	present	(absent)	(not known)
U. Longvillian	*bipartita* *typa* *geniculata*	abundant	(not known)	rare	(not known)

Distribution of Kjaerina.—In Britain *Kjaerina* appears earliest, and is always most abundant, in the more easterly localities. It may be assumed, therefore, that the genus migrated westwards from the zone of East Shropshire and Westmorland. The facts may be summarized in table XI.

KJAERINA HEDSTROEMI Bancroft

Plate 36, figures 7–9; plate 37, figures 1, 2

Kjaerina hedstroemi BANCROFT, 1929, Manchester Lit. Philos. Soc. Mem., vol. 73, no. 4, p. 48, pl. 1, figs. 7–9.

Valves semioval with very small, angular wings, or wings obscure. Ventral valve feebly to rather strongly convex for the genus; dorsal valve flat. Ventral valve without surface wrinkles or more rarely with a few weak oblique wrinkles in posterior region. Ribbing of ventral valve fine, with several stronger ribs in mesial sector and a conspicuously strong mesial rib; ribbing of dorsal valve fine and even. Dental plates narrowly divergent, united anteriorly with subparallel or divergent boundary ridges of muscle area; dental plates and boundary ridges sometimes inseparate. Ventral muscle area impressed but anterior margin indefinite; a narrow adductor ridge situated posteriorly. Interior of dorsal valve with a rather obscure lozenge-shaped or deltoid notothyral platform; anterior angle of notothyral platform produced in a short mesial ridge; crural plates fine; paired cardinal apophyses well developed, lamellar, narrowly divergent.

Variation.—The composite laminae bounding the ventral muscle area present the greatest variation in this species, ranging from the widely divergent type found in *K. jonesi* to the most narrowly divergent type found in the genus. The following may be noted:

1, The dental plates diverge at about 75°; their anterior extremities unite with a pair of fine parallel ridges at the sides of the muscle area. This type is rare in this species.

2, The dental plates are more narrowly divergent than in 1, and the boundary ridges are parallel or slightly divergent. The composite ridges are angulated at the sides and rather short.

3, The dental plates and boundary ridges are narrowly divergent, and form a pair of long, straight, divergent laminae. When the boundary ridges are strongly developed they are inseparable from the dental plates. This is the most distinctive type.

4, The dental plates are short and nar-

rowly divergent, and the boundary ridges are convex to the sides.

Type locality and horizon.—The types are from the fossil bed in dark-grey sandstone exposed at the top of Rookery Wood, Horderley (Bancroft Coll: P17FB1). The horizon is precisely located in the description of *Wattsella lepta*.

Distribution.—At Meifod in Montgomeryshire, Bryn, east of Glyn Ceiriog, and in Southeast Shropshire.

Affinities.—This species is linked through its variations with *K. intermedia* of the subadjacent horizon. It is distinguished from the earlier species by its more narrowly divergent dental plates. The later (Upper Longvillian) forms with narrowly divergent dental plates are distinguished by the presence of strong wrinkles on the exterior of the ventral valve; they are also distinguished by the greater size of their muscle areas and the absence of forms with widely divergent dental plates.

KJAERINA BIPARTITA (Salter)
Plate 37, figures 3, 4

Strophomena bipartita SALTER, 1854, Geol. Soc. London Quart. Jour., vol. 10, p. 74.

Salter's conception of K. bipartita.—Though Salter gave no figures of this species, and both the description and location are rather inadequate, we may, nevertheless, identify the form with complete certainty. The salient points in the original description and the inferences I draw from them are the following:

1, The species is a "*Strophomena*" with a conspicuous mesial rib: "costa mediana maxima elevata in duas partes testam dividente." It is, therefore, a *Kjaerina* and not a *Rafinesquina* of the Shropshire suite.

2, "Localities. Near Hope Bowdler and Cheney Longville, abundant in thin flags (4) of the Horderley section." The only *Kjaerina* horizon exposed in the Hope Bowdler district is the Alternata limestone.

3, "Valva ventralis lente convexa, intra lamellis brevibus ad angulum 90° divaricatis." Species with short and widely divergent dental plates occur only rarely above the Alternata limestone. Such forms occur abundantly in the Alternata limestone.

It is quite clear, therefore, that Salter's species was obtained from the Alternata limestone. The probable, one might almost say obvious location of Salter's types is in the large and fine section in the Alternata beds in the quarry at Soudley, near Hope Bowdler.

Diagnosis.—Valves semioval, with obscure posterolateral wings, c. 30 mm. wide. Ventral valve moderately convex; dorsal valve flat. Surface wrinkles obscure or absent. Ribbing variable, usually rather coarse and strongly differentiated for the genus; consisting near periphery of ribs of four alternating series (a, b, c, d) and a mesial rib (a, d, c, d, b, d, c, d, a); sometimes ribbing finer or less clearly resolved into definite series; a conspicuously strong rib present, the same situated mesially or (more frequently) deflected laterally. Ribbing crossed by very fine and closely set concentric striae. Interior of ventral valve with a pair of short and very slender dental plates diverging at about 90°. Ventral muscle area very shallow, traversed by internal ribbing; anterior margin always, and lateral margin sometimes indefinite; lateral margin usually defined by very fine subparallel ridges, or boundary ridges converging anteriorly; mesial ridge in ventral muscle area broad and depressed, often obscure. Interior of dorsal valve with rather large, flattened, lozenge-shaped notothyral platform. Crural plates very slender. Cardinal process consisting of a pair of rather long, delicate, subparallel plates; a rather obscure mesial ridge present between the paired laminae. Dorsal muscle area indefinite.

Variation.—I note three types of ribbing on the ventral exterior: 1, The ribs of the first order are coarse, sharply elevated and clearly differentiated from those of the second order near the periphery. The ribs of the second, third and fourth orders form graded series alternating with those of the first order and with one another (a, d, c, d, b, d, c, d, a). 2, The ribbing has the same general character as in 1 but is more irregular, and does not form distinct series. 3, The mesial rib is strong and elevated, and is sharply differentiated from the general surface ornament.

Localities and horizon.—The description is based upon material from the lane leading west from Cheney Longville, Southeast Shropshire. The localities are: 1, A good ex-

posure by the north side of the lane, 1340 feet west of the "earth-work" at Cheney Longville (Bancroft Coll: N7). This exposure is not far above the middle of the Alternata limestone. 2, A low exposure by the side of the cart track in the field, a few paces west of N7 (Bancroft Coll: N6).

Associated fauna.—*Dalmanatina apiculata* var., *Bröggerolithus longiceps*, *Brongniartella bisulcata*, *Howellites* sp., *Heterorthis alternata*, *Sowerbyella sericea*.

Affinities.—*K. bipartita* is a derivative of the group of lower Longvillian forms typified by *K. jonesi*. From the other members of that group it is distinguished by its larger size, the coarser character of the ribbing in normal shells, the rather obscure ridge in the ventral muscle area, and the tendency of that muscle area to assume a flabellate form. From *K. hedstroemi* and most of the later species of *Kjaerina* it is distinguished by its more widely divergent dental plates, by the more delicate character of the paired apophyses in the dorsal valve, and, from the later forms, by the absence of strong surface wrinkles on the ventral valve. A rather similar form occurs in the *Onniella aspasia* zone of the Actonian.

KJAERINA GENICULATA Bancroft
Plate 37, figures 5–7

Kjaerina geniculata BANCROFT, 1929, Manchester Lit. Philos. Soc. Mem., vol. 73, no. 4, p. 54, pl. 1, figs. 16, 17.

Valves semioval, parabolic or subtrigonal, with acutely angular wings. Ventral valve gently to abruptly geniculate about a feebly convex disc. Dorsal valve flat. Surface of ventral valve with several strong, oblique or angulated wrinkles in posterior region, or more rarely wrinkles weak or obscure; dorsal exterior with weaker wrinkles. Disc of ventral valve covered by very fine striæ of two or more orders, and traversed by a conspicuous mesial rib; deflected border with ribs in two or three series, the ribs of first series separated by five to eight finer ribs. Dental plates long, narrowly divergent, more or less completely fused with boundary ridges at sides of muscle area. Ventral muscle area forming a well-defined impression with acutely angular diductor lobes, or shallow and without distinct anterior margin. Lateral angles of notothyral platform produced anteriorly forming an "anchor"; paired apophyses of cardinal process short, robust, divergent.

Variation.—The following are measurements of characteristic ventral valves.

Width at hinge	Length of shell	Length of disc	Width of border
38.5 mm.	25.5 mm.	21.0 mm.	5.0 mm.
28.0	21	16	7
28–29	18	13.5	7.5
29	20	15.5	7
c. 19.5 —	15.5	11.5	6.5

The dental plates are almost always narrowly divergent; together with the boundary ridges at the sides of the muscle area they form the following types of composite laminæ: 1, The dental plates and boundary ridges form a pair of straight, narrowly divergent composite plates. 2, The dental plates are long and narrowly divergent, and the lateral boundary ridges are short, subparallel and rather delicate; or the boundary ridges may be long. The composite plates are abruptly angulated at the extremities of the dental plates, and the dental plates are distinct. 3, The dental plates are long, narrowly divergent and inseparable from the boundary ridges; the composite laminæ are narrowly divergent and convex to the sides of the shell. 4, The dental plates are quite short, and the subparallel boundary ridges are very fine or indefinite. This type is relatively rare. 5, The dental plates are short, and the boundary ridges are strongly defined. 6. The boundary ridges may be slightly curved and may partly enclose the muscle area at the front.

Type locality and horizon.—In the north side of the lane leading from Cheney Longville to the Common, 68 yds. east of the first hedge on the north side of the road, west of the "earth-work." The horizon is in the *K. geniculata* zone. I also figure specimens from 80 yards east of the abovementioned hedge.

Affinities.—This species presents the same types of surface wrinkles, ribbing and dental plates as the plano-convex *K. typa*, and is evidently derived from that form through semigeniculate species. It differs from *K. typa* only in the geniculation of its ventral valve. Morphologically both these species may be derived from *K. hedstroemi*, so that we have the following apparent line of

descent: *K. jonesi→K. intermedia→K. hedstroemi→K. typa→K. geniculata.*

Subfamily ORTHOTHETINAE Waagen
Genus KJERULFINA Bancroft

Kjerulfina BANCROFT, 1929, Manchester Lit. Philos. Soc. Mem., vol. 73, no. 4, p. 59.

Genotype, *Kjerulfina trigonalis* Bancroft.

This geniculate strophomenoid appears in the zone of *Wattsella wattsi*, and is represented by characteristic species in the zones of *Wattsella unguis* and *K. polycyma*. At the summit of the Marshbrookian it disappears suddenly and makes no further appearance in the British succession. The genus is known only in the zone of Shropshire and Westmorland and in the Baltic region. The shells figured by Holtedahl (1916) under the name of *Strophomena bröggeri* are quite characteristic examples.

In *Kjerulfina* the geniculate border of the ventral valve is deflected ventrally about a disc that is always convex in its immature region and sometimes in its entirety. The dorsal valve is also geniculate, but in this shell the disc is nearly flat.

KJERULFINA POLYCYMA Bancroft
Plate 38, figures 1–5

Kjerulfina polycyma BANCROFT, 1929, Manchester Lit. Philos. Soc. Mem., vol. 73, no. 4, p. 61, pl. 2, figs. 10–12.

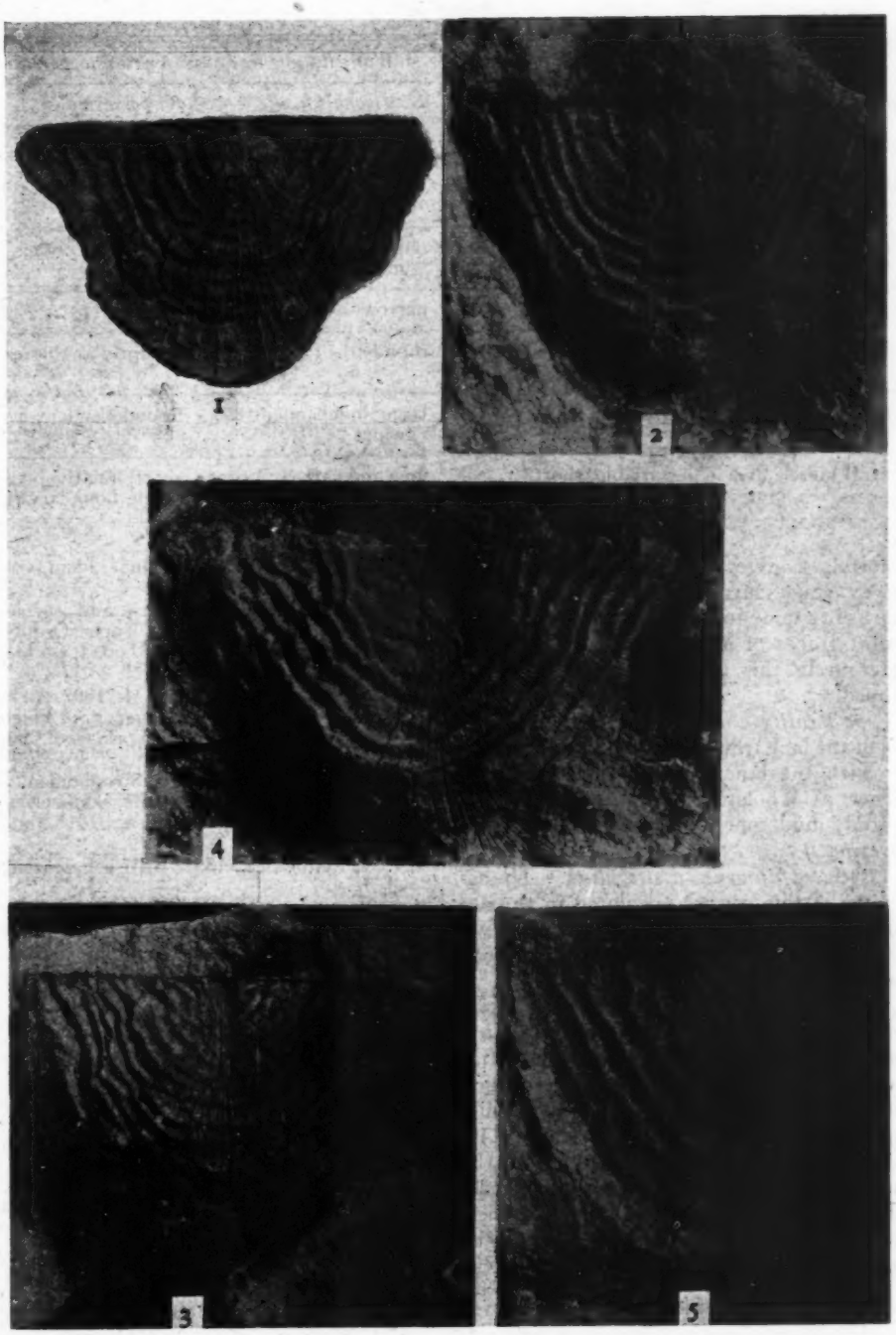
Valves deltoid, about 33 mm. wide; posterolateral angles not produced as independent wings. Ventral valve abruptly geniculate about a convex triangular disc; geniculate border deflected ventrally. Dorsal valve geniculate; disc feebly convex. Surfaces of discs covered with strong, irregular concentric wrinkles, the same sometimes branching; one or two strong wrinkles sometimes present on geniculate border. Ribbing fine, threadlike, even, with two to five stronger ribs in narrow mesial sector; a conspicuously strong mesial rib usually present. Concentric growth striae very fine and closely set. Dental plates short, diverging at 90° to 145°, united at extremities with posterior boundary ridges of muscle area. Boundary ridges of ventral muscle area sharp, abruptly angulated posterolaterally; the posterior ridges in line with dental plates; lateral ridges usually rather short and delicate for the genus, straight or somewhat irregular, converging at a low angle. Ventral muscle area shallow; front indefinite. Crural plates delicate; cardinal process consisting of a pair of delicate subparallel laminae, or laminae more robust; notothyral platform flat, anchor-shaped, the lateral extensions embracing muscle area at sides, and the mesial angle produced as a short ridge; anterolateral margins of platform produced into two or three short, acicular ridges. Dorsal muscle area indefinite, traversed by a pair of delicate longitudinal sinuses on each side of mesial ridge. Interiors of both valves (normally) reproducing fine characters of exterior.

Variation.—The most important variation is a transversely semioval form. This is rather inconspicuous in the assemblages, and seems not to be linked by intermediate types with the deltoid shells; it would seem, therefore, to be a definite variety. Nevertheless it presents the same surface characters, and, except that the boundary ridges of the ventral muscle area appear somewhat stronger, the interiors are identical. The following are measurements of three ventral valves of the deltoid variety: width, c.39, 33, and 32 mm.; length of disc, 17.0, 15.0, and 15.5 mm.; length of shell, 21.0, 20.0, and 20.5 mm.; width of border, 7.5, 8.5 mm. and undetermined.

The other notable variations are: 1, The surface wrinkles, though almost invariably stronger than in earlier forms, are sometimes much weaker than in normal shells, and in rare examples are scarcely stronger than in some specimens of *K. trigonalis*. 2, Abnormally the disc of the ventral valve is not

EXPLANATION OF PLATE 38

FIGS. *1–5*—*Kjerulfina polycyma* Bancroft. *1, 5*, Internal moulds of ventral valves ×2; *2*, internal mould of dorsal valve ×2; *3, 4*, external moulds of ventral valves ×2; *1–3* are from the type locality at Woolston, Southeast Shropshire; *4* is from the *Kjerulfina polycyma* zone of the Onny River section (Bancroft Coll: P8); *5*, from the *K. polycyma* zone in Marsh Wood, Marshbrook, Shropshire (Bancroft Coll: Z4). The shell exhibited in fig. *3* has abnormal types of surface wrinkling and geniculation. (p. 250)



Bancroft, Ordovician Brachiopods

TABLE XII

Zone	*Wattsella wattsi*	*Wattsella unguis*	*Kjerulfina polycyma*
Species	spp.	*K. trigonalis*	*K. polycyma*
Normal width	34–38 mm.	36–40 mm.	c. 33 mm.
Surface wrinkles	fine, weak, few	weak, discontinuous	coarse, strong, continuous
Ventral disc	variable	flat about convex immature zone	uniformly convex
Geniculate border	indefinite	narrow	wide, steep
Axis of geniculation	gently rounded or absent	rounded	abruptly angulate
Posterolateral wings	variable, short	large, independent wings	no independent wings
Ventral muscle area	variable, short	long and narrow; strong boundary ridges	short, relatively wide; fine boundary ridges

uniformly convex but presents an earlier convex stage surrounded by a depressed zone as in some earlier species. 3, Some shells exhibit traces of an anterior buttress, and more rarely this feature may be well developed.

Type locality and horizon.—At the junction of the lane from Woolston to Whittingslow with the lane from Woolston to The Corner, at Woolston (Bancroft Coll: L12). In sandy mudstones of the zone of *Kjerulfina polycyma*.

Associated fauna and distribution.—The associates of this species are noted in the account of *Onniella reuschi*. The form is known only in Southeast Shropshire and the Dufton shales of Westmorland.

Affinities.—Through its abnormal variations *K. polycyma* is linked with *K. trigonalis* (Bancroft, 1929) from the subadjacent zone, and it is most probably descended from that species. The most important distinctive characters are set out in Table XII. The earliest species of *Kjerulfina* (from the zone of *Wattsella wattsi*) are not sufficiently well known to merit description, and their characters as set out in the table should be regarded with reserve.

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JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, PP. 253–276, PLS. 39–41, 1 TEXT FIG., MAY 1945

JURASSIC FOSSILS FROM THE SOUTHERN STATES, NO. 2[1]

RALPH W. IMLAY
United States Geological Survey, Washington, D. C.

ABSTRACT—Fossils from deeply buried sedimentary rocks of eastern Texas, southern Arkansas, northern Louisiana, and southwestern Alabama show that the Upper Jurassic sequence consists of the Eagle Mills, Smackover, Buckner, and Cotton Valley formations. They show that the lower part of the Cotton Valley formation is of Kimmeridgian age, and that the Smackover limestone is of Argovian age. The Buckner formation, lying between these formations, is assigned to the early Kimmeridgian on the basis that probable equivalent marine beds in northern Louisiana contain lower Kimmeridgian ammonites, and that similar gypsiferous beds in northern Mexico appear to be of that age. The nonfossiliferous Eagle Mills formation underlies the Smackover formation gradationally, as observed in well cores, and cannot be much older. The fossils described herein include 20 species of pelecypods, 6 species of gastropods, and 10 species of ammonites. Of these, 5 species are described as new, 4 are identified with species in the Upper Jurassic of northern Mexico and western Texas, 9 are compared with species in the same regions, and 9 are compared with European species.

INTRODUCTION

SINCE publication of descriptions of Jurassic fossils from Arkansas, Louisiana, and eastern Texas (Imlay, 1941; Wells, 1942), many additional Jurassic fossils from these states have been assembled, plus a valuable collection from a deep well drilled in late 1941 on the Hatchetigbee anticline of southwestern Alabama. Particular effort was made to obtain fossils from the Cotton Valley and Morehouse formations, which preliminary studies indicated were of Jurassic age, in order to determine their exact ages. Study of the fossils has shown definitely that the Cotton Valley formation is of late Upper Jurassic age, and the Morehouse formation is of Upper Paleozoic age. Examination of fossils from the Buckner and Smackover formations of Alabama permits a correlation across the Mississippi embayment. Determination of the ages of these formations makes possible a better understanding of the paleogeography of the Gulf region and will undoubtedly influence petroleum exploration.

ACKNOWLEDGMENTS

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FOSSIL MATERIAL

The fossils described herein were obtained from 18 wells of which one is located in southwestern Alabama, 10 in southern Arkansas, six in northern Louisiana, and one in eastern Texas. The location of these wells

[1] Number 1 of this series is "Jurassic fossils from Arkansas, Louisiana, and eastern Texas" (Imlay, 1941).

TABLE 1. WELLS FROM WHICH JURASSIC FOSSILS HAVE BEEN OBTAINED

Field or structure	Company	Well	Location	County or Parish and State	Elevation D.F.	Top of Cotton Valley	Top of Buckner	Top of Smackover	Top of Eagle Mills	Total depth
Hatchetigbee anticline	Union Producing	M. M. Waite no. 1	1406 ft. S., 1389 ft. E. of NW. cor. sec. 27, T. 8 N., R. 1 W.	Clarke, Alabama	38	9,395	11,500	11,782	12,291	12,399
North Lisbon	Union Producing	McDonald unit no. 1	1360 ft. E., 1358 ft. N. of SW. cor. of sec. 13, T. 21 N., R. 5 W.	Claiborne, Louisiana	322	7,491	11,470	11,808		12,591
North Lisbon	Union Producing	Z. J. Meadows no. 1-A	1322 ft. S., 1294 ft. W. of NE. cor. of sec. 18, T. 21 N., R. 4 W.	Claiborne, Louisiana	242	7,416	absent	10,157 or 10,247	11,806	11,834
Wildcat	W. J. Furlong, Jr.	E. M. Clark no. 1	876 ft. N., 639 ft. W. of SE. cor. SE.¼ NE.¼ sec. 10, T. 20 N., R. 7 E.	Morehouse, Louisiana	102	3,125 or 2,830	5,645	6,140		7,023
Haynesville	Ohio Oil and Gulf Refining	G. W. Taylor no. 15	100 ft. S., 100 ft. W., of cen. of SE.¼ sec. 15, T. 23 N., R. 8 W.	Claiborne, Louisiana	337	7,129	10,553	10,956		11,274
Smackover	Gulf Refining	Louis Werner Sawmill Co. no. 49	4620 ft. N., 60 ft. E. of SW. cor. sec. 5, T. 16 S., R. 16 W.	Union, Arkansas	128	4,066	5,753	5,920	6,597	7,973
Rodessa	R. W. Norton	John E. Payne no. 1	660 ft. N., 660 ft. W. of SE. cor. sec. 27, T. 23 N., R. 16 W.	Caddo, Louisiana	221	8,088	9,955	10,197	11,403	11,475
Mexia	Pure Oil	W. B. Kendricks no. T-16	1470 ft. fr. SE. line, 723 ft. from SW. line of W. B. Kendrick's 96.2 acre tract in the P. Varela H.R.S.	Limestone, Texas	517	7,676	8,522	8,765		8,847
McKamie	Normandie Oil	R. R. Cornelius no. 1	Cen. NW.¼ SW.¼ sec. 28, T. 17 S., R. 23 W.	Lafayette, Arkansas	271	6,782	8,966	9,125		9,347
Magnolia	Normandie Oil	C. E. Crumpler no. 1	Cen. S. 30 acres of SW.¼ SE.¼ sec. 18, T. 17 S., R. 19 W.	Columbia, Arkansas	269	5,270	7,347	7,486		7,518
Magnolia	Normandie Oil	C. E. Crumpler no. B-1	Cen. S. 30 acres of SE.¼ SE.¼ sec. 18, T. 17 S., R. 19 W.	Columbia, Arkansas	275	5,360	7,360	7,501		7,523
Magnolia	Louark Prod.	A. W. Gunnels B-2	660 ft. N. & W. of SE. cor. NE.¼ NW.¼ sec. 20, T. 17 S., R. 19 W.	Columbia, Arkansas	262	5,270	7,348	7,471		7,519
McKamie	Carter Oil	R. R. Cornelius no. 2	1220 ft. S., 1320 ft. W. of NE. cor. sec. 31, T. 17 S., R. 23 W.	Lafayette, Arkansas	277	6,867	8,966	9,086		9,350
Buckner	Standard Oil	Nancy Johnson B-1	655 ft. W., 660 ft. N. of SE. cor. of sec. 9, T. 16 S., R. 22 W.	Columbia, Arkansas	295	5,384	7,020	7,268		7,324
Midway	Barnsdall Oil	B. H. Dobson no. 1	Cen. SE.¼ NE.¼ sec. 10, T. 15 S., R. 24 W.	Lafayette, Arkansas	293	4,927	6,228	6,414		6,504
Midway	Barnsdall Oil	E. S. Bond no. 1	Cen. NW.¼ SW.¼ sec. 11, T. 15 S., R. 24 W.	Lafayette, Arkansas	272	4,897	6,151	6,307		6,537
Atlanta	J. K. Mahoney, et al.	Emma Riley no. 1	Cen. NW.¼ NE.¼ sec. 14, T. 18 S., R. 19 W.	Columbia, Arkansas	210	5,880	not present	8,143		8,237
Magnolia	Standard Oil	A. W. Gunnells no. 1	SW.¼ NW.¼ sec. 20, T. 17 S., R. 19 W.	Columbia, Arkansas	312	5,448	7,408	7,496		7,587

TABLE 2. JURASSIC FOSSILS OF THE GULF REGION STUDIED FOR THIS REPORT

Species	Well	Depth	Formation	Location			
				Twp.	R.	Sec.	State
Thamnasteria imlayi Wells	Carter-Cornelius no. 2	9200	Smackover	17 S.,	23 W.,	31,	Ark.
Thamnasteria imlayi Wells	Standard-Gunnels no. 1	7536	Smackover	17 S.,	19 W.,	20,	Ark.
Astrocoenia? sp.	Barnsdall-Bond no. 1	6332 –52	Smackover	15 S.,	24 W.,	11,	Ark.
Mytilus cf. *M. jurensis* Merian	Union-Waite no. 1	11803½–15½	Smackover	8 N.,	1 W.,	27,	Ala.
Mytilus sp.	Pure-Kendricks no. T-16	7725 –35	Cotton Valley	Limestone Co., Texas			
Trigonia calderoni (Costillo and Aguilera)	Union-McDonald no. 1	10822 –27	Cotton Valley	21 N.,	5 W.,	13,	La.
Trigonia aff. *T. vyschetzkii* Cragin	Union-McDonald no. 1	10822 –27	Cotton Valley	21 N.,	5 W.,	13,	La.
Ostrea (*Catinula*) *broughtoni* Imlay	Furlong-Clark no. 1	5254 –55	Cotton Valley	20 N.,	7 E.,	10,	La.
Ostrea (*Lopha*) sp.	Union-Waite no. 1	11803½–15½	Smackover	8 N.,	1 W.,	27,	Ala.
Exogyra cf. *E. virgula* (Defrance)	Ohio & Gulf-Taylor no. 15	9565 –66	Cotton Valley	23 N.,	8 W.,	15,	La.
Exogyra sp.	Union-Waite no. 1	11803½–15½	Smackover	8 N.,	1 W.,	27,	Ala.
Exogyra sp.	Union-Meadows no .1	8957 –58	Cotton Valley	21 N.,	4 W.,	18,	La.
Pecten (*Syncyclonema?*) sp.	Union-Waite no. 1	11669 –71	Smackover	8 N.,	1 W.,	27,	Ala.
Pecten (*Syncyclonema?*) sp.	Union-Meadows no. A-1	9898 –9903	Cotton Valley	21 N.,	4 W.,	18,	La.
Camptonectes? sp.	Normandie-Cornelius no. 1	9351 –66	Smackover	17 S.,	23 W.,	28,	Ark.
Pseudomonotis louisianensis Imlay	Union-Meadows no. A-1	8967 –9131	Cotton Valley	21 N.,	4 W.,	18,	La.
Pseudomonotis durangensis Imlay	Union-Meadows no. A-1	9118 –23	Cotton Valley	21 N.,	4 W.,	18,	La.
Posidonia cf. *P. ornati* Quenstedt	Gulf-Werner no. 49	6440 –6587	Smackover	16 S.,	16 W.,	5,	Ark.
Pteropema? sp.	Union-McDonald no. 1	8680 –82	Cotton Valley	21 N.,	5 W.,	13,	La.
Gervillia aff. *G. corrugata* Cragin	Union-Waite no. 1	11803½–15½	Smackover	8 N.,	1 W.,	27,	Ala.
Astarte breviacola Cragin	Union-McDonald no. 1	10835 –39	Cotton Valley	21 N.,	5 W.,	13,	La.
Astarte grubbi Imlay	Louark-Gunnels no. B-2	7490 –95	Smackover	17 S.,	19 W.,	20,	Ark.
Astarte grubbi Imlay	Standard-Johnson no. B-1	7312 –14	Smackover	16 S.,	22 W.,	9,	Ark.
Astarte grubbi Imlay	Carter-Cornelius no. 2	9200	Smackover	17 S.,	23 W.,	31,	Ark.
Astarte aff. *A. valfinensis* P. de Loriol	Union-McDonald no. 1	10959 –69	Cotton Valley	21 N.,	5 W.,	13,	La.
Astarte (*Coelastarte*) cf. *A. rathieri* P. de Loriol	Union-Waite no. 1	11803½–12250	Smackover	8 N.,	1 W.,	27,	Ala.
Opis (*Trigonopis*) cf. *O. curvirostra* (W. Smith)	Standard-Gunnels no. 1	7532 –52	Smackover	17 S.,	19 W.,	20,	Ark.
Trapezium? cf. *T. subtrigonum* Imlay	Union-Waite no. 1	11669 –71	Buckner	8 N.,	1 W.,	27,	Ala.
Corbicella? cf. *C. laevis* (J. de C. Sowerby)	Norton-Payne no. 1	9406 –21	Cotton Valley	23 N.,	16 W.,	27,	La.
Corbicella? sp.	Union-Meadows no. A-1	8997 –9002	Cotton Valley	21 N.,	4 W.,	18,	La.
Quenstedtia weeksi Imlay	Union-McDonald no. 1	11661 –63	Buckner	21 N.,	5 W.,	13,	La.
Quenstedtia spearsi Imlay	Union-McDonald no. 1	11661 –63	Buckner	21 N.,	5 W.,	13,	La.
Eocallista? cf. *E. ?cuneovatus* (Cragin)	Standard-Johnson no. B-1	7283 –7315	Smackover	16 S.,	22 W.,	9,	Ark.
Cercomya? sp.	Union-Waite no. 1	11803½–15½	Smackover	8 N.,	1 W.,	27,	Ala.
Pholadomya cf. *P. hemicardia* Roemer	Union-Waite no. 1	11803½–15½	Smackover	8 N.,	1 W.,	27,	Ala.
Purpurina (*Eucycloidea?*) sp.	Barnsdall-Bond no. 1	6352 –62	Smackover	15 S.,	24 W.,	11,	Ark.
Cryptoptyxis? diversicostata Imlay	Carter-Cornelius no. 2	9200	Smackover	17 S.,	23 W.,	31,	Ark.
Xystrella? aff. *X. papillosa* (Deslongchamps)	Carter-Cornelius no. 2	9200	Smackover	17 S.,	23 W.,	31,	Ark.
Gymnocerithium? aff. *G. josephense* (P. de Loriol)	Barnsdall-Bond no. 1	6352 –62	Smackover	15 S.,	24 W.,	11,	Ark.
Ceritella? sp.	Barnsdall-Dobson no. 1	6429 –30	Smackover	15 S.,	24 W.,	10,	Ark.
Phaneroptyxis angulata Imlay	Louark-Gunnels no. B-2	7490 –95	Smackover	17 S.,	19 W.,	20,	Ark.
Phaneroptyxis angulata Imlay	Barnsdall-Dobson no. 1	6429 –30	Smackover	15 S.,	24 W.,	10,	Ark.
Phaneroptyxis angulata Imlay	Barnsdall-Bond no. 1	6317 –32	Smackover	15 S.,	24 W.,	11,	Ark.
Nerinea cf. *N. turbatrix* P. de Loriol	Standard-Johnson no. B-1	7281	Smackover	16 S.,	22 W.,	9,	Ark.
Nerinea? lafayettensis Imlay	Barnsdall-Bond no. 1	6352 –62	Smackover	15 S.,	24 W.,	11,	Ark.
Nerinea? helicata Imlay	Normandie-Crumpler no. B-1	7518	Smackover	17 S.,	19 W.,	18,	Ark.
Aptyxiella (*Nerinoides*)? aff. *A. stantoni* (Cragin)	Carter-Cornelius no. 2	9200	Smackover	17 S.,	23 W.,	31,	Ark.
Metahaploceras cf. *M. nereus* (Fontannes)	Phillips-Kendricks no. 1	7654 –64	Cotton Valley	19 N.,	11 W.,	22,	La.
Glochiceras fialar (Oppel) of Burckhardt	Phillips-Kendricks no. 1	8048 –63	Cotton Valley	19 N.,	11 W.,	22,	La.
Idoceras cf. *I. complanatum* Burckhardt	Phillips-Kendricks no. 1	8048 –63	Cotton Valley	19 N.,	11 W.,	22,	La.
Idoceras cf. *I. durangense* Burckhardt	Phillips-Kendricks no. 1	8048 –63	Cotton Valley	19 N.,	11 W.,	22,	La.
Idoceras cf. *I. lorioli* Burckhardt	Phillips-Kendricks no. 1	8048 –63	Cotton Valley	19 N.,	11 W.,	22,	La.
Idoceras (*Subnebrodites*)? sp.	Phillips-Kendricks no. 1	8377 –92	Cotton Valley	19 N.,	11 W.,	22,	La.
Ataxioceras sp.	Phillips-Kendricks no. 1	8279 –94	Cotton Valley	19 N.,	11 W.,	22,	La.
Ataxioceras sp.	Phillips-Kendricks no. 1	8377 –92	Cotton Valley	19 N.,	11 W.,	22,	La.
Dichotomosphinctes? sp.	Phillips-Kendricks no. 1	8741 –56	Smackover	19 N.,	11 W.,	22,	La.
Discosphinctes cf. *D. virgulatus* (Quenstedt) of Burckhardt	Phillips-Kendricks no. 1	8741 –56	Smackover	19 N.,	11 W.,	22,	La.
Discosphinctes cf. *D. lucingensis* (Choffat) of Burckhardt	Phillips-Kendricks no. 1	8741 –56	Smackover	19 N.,	11 W.,	22,	La.

and the upper limits of the Jurassic formations encountered in them are shown in table 1.

The fossils are preserved mainly as external and internal molds. Internal molds from the Buckner and Cotton Valley forma-

tions generally retain some shell material. Specimens of *Pseudomonotis*, *Ostrea*, *Exogyra*, *Posidonia*, and brachiopods retain considerable shell material.

Described fossils include 20 species of pelecypods distributed among 18 genera, 6 species of gastropods distributed among 4 genera, and 10 species of ammonites. A few species have been redescribed or refigured on the basis of better material. The molluscan genera and species are listed in table 2.

TABLE 3. COMPARISON OF FOSSILS FROM THE SMACKOVER FORMATION

Species from the Smackover formation of the Gulf region	Similar species	Range and occurrence of similar species	
Mytilus cf. *M. jurensis* Merian	*M. jurensis* Merian	Argovian	Europe
Posidonia cf. *P. ornati* Quenstedt	*P. ornati* Quenstedt	Aalenian-Callovian	World wide
Gervillia cf. *G. corrugata* Cragin	*G. corrugata* Cragin	Kimmeridgian	West Texas
Astarte grubbi Imlay	*A. fimbriata* Walton	Bathonian	Europe
Astarte (*Coelastarte*) cf. *A. ralhieri* P. de Loriol	*A. rathieri* P. de Loriol	Kimmeridgian	France
Astarte (*Coelastarte*) *hazzardi* Imlay	*A. rectangula* Arkell	Argovian	England
Opis (*Coelopis*) *americana* Imlay	*O. portlandica* P. de Loriol	Portlandian	Europe
Quenstedtia weeksi Imlay	*Q. gibbosa* Hudleston	Argovian	England
Pholadomya cf. *P. hemicardia* Roemer	*P. hemicardia* Roemer	Argovian-Kimmeridgian	Europe
Xystrella? aff. *X. papillosa* (Deslongchamps)	*X. papillosa* (Deslongchamps)	Bajocian	Europe
Cryptoptyxis? formosa Imlay	*"Pseudocerithium" contortum* Brösamlen	Middle Jurassic	Germany
Cryptoptyxis? aff. *C. grimaldi* (Guirand and Ogerian)	*C. grimaldi* (Guirand and Ogerian)	Argovian	Europe
Gymnocerithium? aff. *G. josephense* (P. de Loriol)	*G. josephense* (P. de Loriol)	Argovian	Europe
Phaneroptyxis angulata Imlay	*P. moreana* (d'Orbigny)	Argovian-Sequanian	Europe
Nerinea aff. *N. eudesii* Morris and Lycett	*N. eudesii* Morris and Lycett	Middle Jurassic	Europe
Nerinea cf. *N. turbatrix* P. de Loriol	*N. turbatrix* P. de Loriol	Sequanian	Europe
Aptyxiella (*Nerinoides*)? aff. *A. stantoni* (Cragin)	*A. stantoni* (Cragin)	Kimmeridgian	West Texas
Disosphinctes sp.	*D. virgulatus* (Quenstedt) in Burckhardt	Upper Argovian	Mexico
Discosphinctes? sp.	*D. lucingensis* (Choffat) in Burckhardt	Upper Argovian	Mexico
Dichotomosphinctes? sp.	*D. plicatilis* (DeRiaz) in Burckhardt	Upper Argovian	Mexico

CORRELATION

Eagle Mills formation.—No fossils have been found in the Eagle Mills formation, but its gradational relationship with the overlying Smackover limestone, as observed in well cores, and the presence of upper Argovian ammonites only 300 feet above the bedded salt shows that it cannot be much older. It was probably formed at the same time as the salt and red beds underlying Upper Jurassic limestones in southern Mexico (Burckhardt, 1930, pp. 96, 97; Imlay, 1940, pp. 12, 13), as both areas of salt deposition were undoubtedly connected with the Gulf of Mexico and were under similar climatic control. The salt and red beds of southern Mexico appear to be part of the Upper Jurassic sequence, according to Paul Weaver (personal communication). Their origin at a time older than Divesian seems unlikely, considering (1) that the Callovian and the older Jurassic of southern Mexico are well represented by marine

faunas (Burckhardt, 1930, pp. 8–44) that could not have existed in a highly saline environment; (2) that the Lower and Middle Jurassic beds have furnished a rich flora which, according to Wieland (1913, p. 256), indicates a tropical climate of the monsoon forest type, and (3) that in many parts of

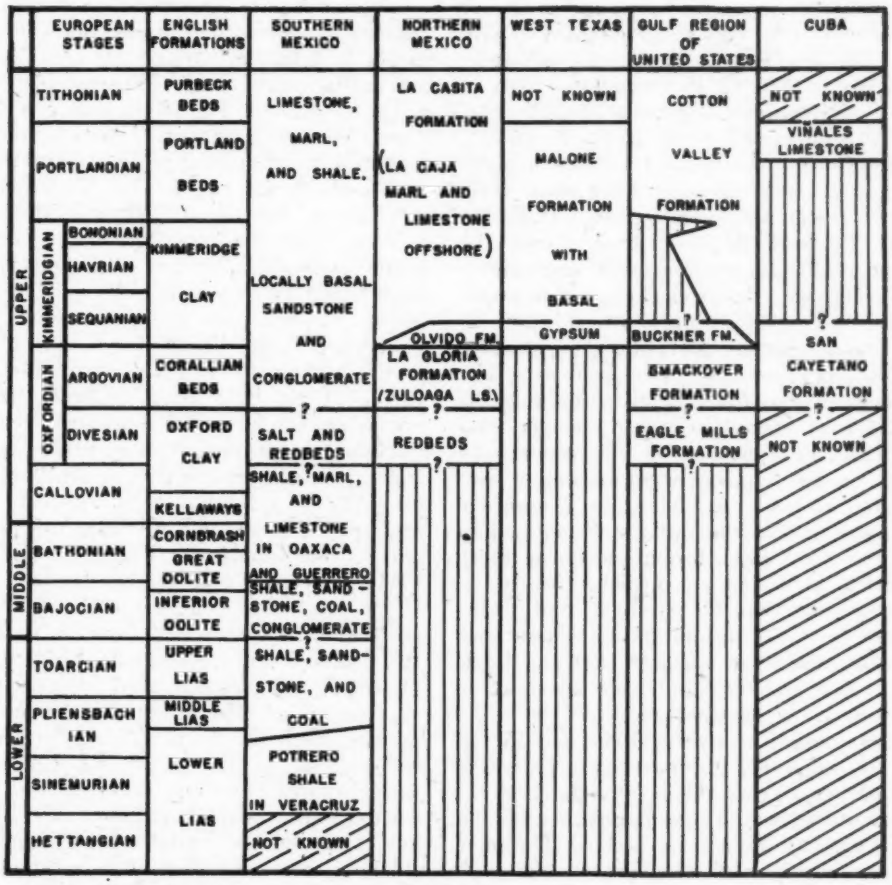

FIG. 1—Correlation of the Jurassic formations of the Gulf region.

Mexico the rocks of Oxfordian age are marked basally by a pronounced disconformity (Burckhardt, 1930, p. 100; Kellum, 1936, pp. 1057, 1065) that is not apparent at the top of the salt section.

Smackover formation.—Evidence has been presented previously that the Smackover formation is not older than Callovian or younger than Argovian (Imlay, 1941, pp. 262, 263). Nearly all the mollusks obtained from the Smackover formation are from its upper oolitic and coralline part, and most of them are comparable to species of Argovian or Kimmeridgian age (table 3). However, the presence of a gastropod, apparently identical with *Xystrella*, suggests an age not younger than Argovian. This assignment is substantiated (1) by the presence of ammonites comparable to species of *Dichotomosphinctes* and *Discosphinctes* from upper Argovian beds in eastern Durango, Mexico, and (2) of Kimmeridgian fossils in the lower part of the overlying Cotton Valley formation. Likewise, regional stratigraphic relationships indicate that the

upper part of the Smackover formation is equivalent to the upper part of the La Gloria formation of northern Mexico (fig. 1) which contains upper Argovian ammonites. Whether any of the Smackover formation is older than Argovian time is not known, but its thickness of only 450 to 1650 feet and the presence of upper Argovian ammonites only 300 feet above its base suggest that it is not older. The only fossil obtained to date from the basal beds of the Smackover formation is *Posidonia* cf. *P. ornati* Quenstedt in the Gulf Refining Company's Louis Werner no. 49 well in sec. 5, T. 16 S., R. 16 W., Union County, Arkansas. Its presence might suggest a Callovian age for the basal beds, as *P. ornata* has been recorded from the upper Lias to Callovian in many parts of the world, and the genus *Posidonia* is rare above the Callovian. However, an age determination based on such a highly variable form as *Posidonia* cannot have much significance unless supported by other evidence. The presence of *Posidonia* merely shows that the Smackover formation is not younger than Jurassic. For purposes of this report, the base of the Smackover formation is considered of lower Argovian age (1) on the assumption that the formation is equivalent to the La Gloria formation of northern Mexico, which has not furnished fossils definitely older than the Argovian, and (2) because certain stratigraphic considerations, already discussed, indicate that the Eagle Mills salt and its counterpart in southern Mexico are of Divesian age.

Previously the writer (1939, pp. 15, 21, 33, 34) suggested that part of the La Gloria formation was as old as Divesian, on the basis of fragmentary ammonites found near Las Cuevas Ranch in eastern Durango. These ammonites were provisionally assigned to the genera *Subgrossouvria*, *Indosphinctes*, and *Pseudopeltoceras*. However, on reconsideration, the fragments assigned to *Subgrossouvria* (Imlay, 1939, p. 33, pl. 5, fig. 8) are similar to the outer whorls of the genus *Perisphinctes* (strict sense), as interpreted by Arkell (1937, pp. lii–liv), and the fragments assigned to *Indosphinctes* (Imlay, 1939, p. 34, pl. 7, figs. 1, 7; pl. 8, figs. 1, 2; text fig. 7) greatly resemble the upper Argovian genus *Decipia* (Arkell, 1937, pp. 44–48). An upper Argovian age for these Mexican ammonites is also suggested by their stratigraphic position only 855 feet below the top of the La Gloria formation, which near San Pedro del Gallo in eastern Durango has furnished upper Argovian ammonites at a comparable position.

Buckner formation.—The age of the Buckner formation must be early Kimmeridgian or late Argovian but cannot be determined exactly on the basis of its meager available fauna of ostracodes, phyllopods, and marine pelecypods. The ostracodes have not been studied. The phyllopods comprise several species of *Estheria* that are similar to long-ranging Mesozoic species (Imlay, 1941) p. 276, pl. 39, figs. 22–29). One of the species of *Estheria* is common to the Buckner formation and the basal part of the Cotton Valley formation. Marine pelecypods have been found in only two wells and are referred to the genera *Quenstedtia* and *Trapezium*. The Union Producing Company's McDonald no. 1 well, located in sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana, has furnished many specimens of *Quenstedtia weeksi* Imlay and *Q. spearsi* Imlay from the middle part of the Buckner formation at a depth of 11,661–63 feet. The first species is known also from the upper part of the Smackover limestone (Imlay, 1941, p. 272, pl. 38, figs. 18, 24, 25). The Union Producing Company's M. M. Waite no. 1 well, located in sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama, at a depth of 11,669–71 feet, has furnished one specimen of *Trapezium?* that appears to be an immature form of *Trapezium? subtrigonum* Imlay (1941, p. 270, pl. 38, fig. 41) which was obtained from the lower part of the Cotton Valley formation of northern Louisiana. Thus the few available fossils from the Buckner formation show close relationship with fossils in adjoining formations and thereby indicate that it represents a very small time interval.

Regional relationships indicate that the Buckner formation is of lower Kimmeridgian age, as probable equivalent marine shales have furnished the ammonites *Ataxioceras* and *Idoceras* at depths of 8279–94 and 8377–92 feet in the Phillips Petroleum Company's Kendrick no. 1 well, located in sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana. *Ataxioceras* ranges down into the Argovian

but is most characteristic of the lower Kimmeridgian. *Idoceras* ranges through the lower Kimmeridgian into the base of the middle Kimmeridgian. Therefore the association of these genera proves the lower Kimmeridgian age of the beds in which they occur. This age assignment is confirmed by the presence at depths of 8048–63 feet of basal middle Kimmeridgian ammonites, including *Idoceras* cf. *I. durangense* Burckhardt and *Glochiceras fialar* (Oppel), and by the presence at depths of 8741–56 feet of ammonites similar to species of *Dichotomosphinctes* and *Discosphinctes* that characterize beds of upper Argovian age in eastern Durango, Mexico.

The Buckner formation appears to be the stratigraphic equivalent of the thick masses of gypsum at the base of La Casita formation in the Sierra Madre Oriental and elsewhere in Mexico (Böse, 1923, pp. 130, 131, 203; Burckhardt, 1930, pp. 84–87, 102, 103; Baker, 1936, p. 496) in areas adjoining Jurassic land masses. The exact age of the gypsum has not been determined, but Burckhardt (1930, p. 86, tables 8, 9) considers it to be earliest Kimmeridgian. Deposition of the gypsum during this time may explain why no Kimmeridgian deposits older than the beds with *Idoceras* group of *I. balderus* have yet been identified in northern Mexico although richly developed in southern Mexico (Burckhardt, 1930, pp. 64, 66). The formation of extensive gypsum masses around the northern and eastern margins of the Mexican sea suggests that little or no sediment was deposited seaward from the marginal lagoons.

The Buckner formation likewise appears to be equivalent stratigraphically to the thick nonfossiliferous gypsum masses at the base of the Malone formation in western Texas. This gypsum was included by Albritton (1938, pp. 1753–1757) in his Briggs formation and assigned to the Permian on the basis of an unconformity at the top and of Permian fossils in a black limestone at the base. However, the unconformity at the top of the gypsum may correspond to the unconformity at the top of the Buckner formation. The probability that gypsum could exist as a surface formation from Permian until Upper Jurassic time is extremely unlikely. The presence of Permian gypsum in the Malone Mountain area does not accord with present ideas of Permian paleogeography (Albritton, 1938, p. 1756; King, 1942, pp. 739, 742, 744). The position of the gypsum at the base of beds of Kimmeridgian age is identical with the position of similar deposits in Mexico and the Gulf region of the United States.

Cotton Valley formation.—Definite proof of the late Upper Jurassic age of the Cotton Valley formation is furnished by ammonites from the lower part of the formation at depths of 8048–63 feet in the Phillips Petroleum Company's Kendricks no. 1 well located in sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana. The fossils occurring at these depths furnish an exact correlation with the basal middle Kimmeridgian of Mexico and may be listed as follows:

Idoceras cf. *I. durangense* Burckhardt.
Idoceras cf. *I. lorioli* Burckhardt.
Idoceras cf. *I. complanatum* Burckhardt.
Glochiceras fialar (Oppel) of Burckhardt.
Taramelliceras? sp.
Haploceras sp.
Physodoceras? sp.
Lamellaptychus sp.
Pteroperna? sp.
Fish scales.
Fish skull bones.

Other proof of the Jurassic age of the Cotton Valley formation is furnished by several pelecypod species identical with Upper Jurassic species from Mexico or from the Malone Mountains of western Texas. These include *Trigonia calderoni* (Castillo and Aguilera), *Pseudomonotis durangensis* Imlay, and *Astarte breviacola* Cragin. The first two species are known from beds of Argovian and Kimmeridgian age and the latter species only from the Kimmeridgian, but none of the species is known from beds higher than the *Idoceras* zone of the lower part of the Kimmeridgian. The presence of these species in the lower part of the Cotton Valley formation is strong evidence of its Kimmeridgian age, considering that the upper part of the underlying Smackover limestone appears to be not younger than Argovian.

Definite evidence of the Kimmeridgian age of the lower part of the Cotton Valley formation is furnished, likewise, by the oc-

currence of the pelecypod *Aulacomyella* in the Phillips Petroleum Company's Kendricks no. 1 well, Bossier Parish, Louisiana, and in the Union Producing Company's Z. J. Meadows no. 1 well of Claiborne Parish, Louisiana. *Aulacomyella* resembles the Upper Triassic genus, *Halobia*, and is easily recognized by its sculpture. It is of unusual stratigraphic value, as it has been recorded only from the middle Kimmeridgian, and in Mexico is known only from the lower part of the middle Kimmeridgian in association with *Glochiceras fialar* (Oppel) and species of the *Idoceras durangense* group (Burckhardt, 1930, pp. 51, 67, 86, 90, 92, 96, 97).

Other species from the lower part of the Cotton Valley formation, as listed on table 4, are mainly comparable to species of Kimmeridgian age. One of these is a finely ribbed *Exogyra* apparently identical with *E. virgula* (Defrance) which, in Europe, is characteristic of the middle Kimmeridgian (Havrian) but ranges down through most of the lower Kimmeridgian (Sequanian). The occurrence of an *Exogyra* with the same distinctive ornamentation as *E. virgula* strongly suggests a Kimmeridgian age.

Only a few fossils have been obtained from the upper part of the Cotton Valley formation. The Pure Oil Company's Kendricks no. T-16 well in Limestone County, Texas, has furnished a few specimens of *Mytilus* and *Astarte* that are of no value for any age determination. The Gulf Oil Company's Goodpine no. 1 well in Bienville Parish, Louisiana, has furnished *Tancredia louisianensis* Imlay about 100 feet below the top of the Cotton Valley formation. This species belongs to the group of *T. axiniformis* (Cox, 1929, p. 573), which ranges into the Lower Cretaceous but is rare above the Jurassic.

The Cotton Valley formation is considered to be the equivalent of the La Casita formation of Mexico (Imlay, 1938, pp. 1683–1687). The formations are very similar lithologically, are apparently of the same age at their base, occupy the same stratigraphic position relative to adjoining formations, and were probably formed under similar environmental conditions.

SYSTEMATIC DESCRIPTIONS

Genus MYTILUS Linnaeus, 1758

MYTILUS cf. M. JURENSIS Merian

Plate 39, figures 7–9

The species is represented by an internal mold of both valves that lacks part of the beak region and by an external mold of the

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EXPLANATION OF PLATE 39

FIGS. *1–4—Pseudomonotis durangensis* Imlay. *1*, Left valve of plesiotype, U. S. Nat. Mus. 103630a, Cotton Valley formation, Union-Meadows no. A-1 well at depths of 9118–23 feet, ×1; *2–4*, left valves of plesiotypes, U. S. Nat. Mus. 103674a–c, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 6367–82 feet, ×1. (p. 263)

5, 6—Gervillia aff. *G. corrugata* Cragin. Specimen, U. S. Nat. Mus. 103634, Smackover limestone, Union-Waite no. 1 well at depths of 11803½–15½ feet, ×1 and ×2. (p. 265)

7–9—Mytilus cf. *M. jurensis* Merian. Lateral and ventral views of specimen, U. S. Nat. Mus. 103625, Smackover limestone, Union-Waite no. 1 well at depths of 11803½–15½ feet, ×2. (p. 260)

10, 14, 18—Pteroperna? sp. Specimen, U. S. Nat. Mus. 103633, Cotton Valley formation, Union-McDonald no. 1 well at depths of 8680–82 feet, ×1. (p. 264)

11—Trigonia calderoni (Castillo and Aguilera). Plesiotype, U. S. Nat. Mus. 103626, Cotton Valley formation, Union-McDonald no. 1 well at depths of 10822–27 feet, ×1. (p. 261)

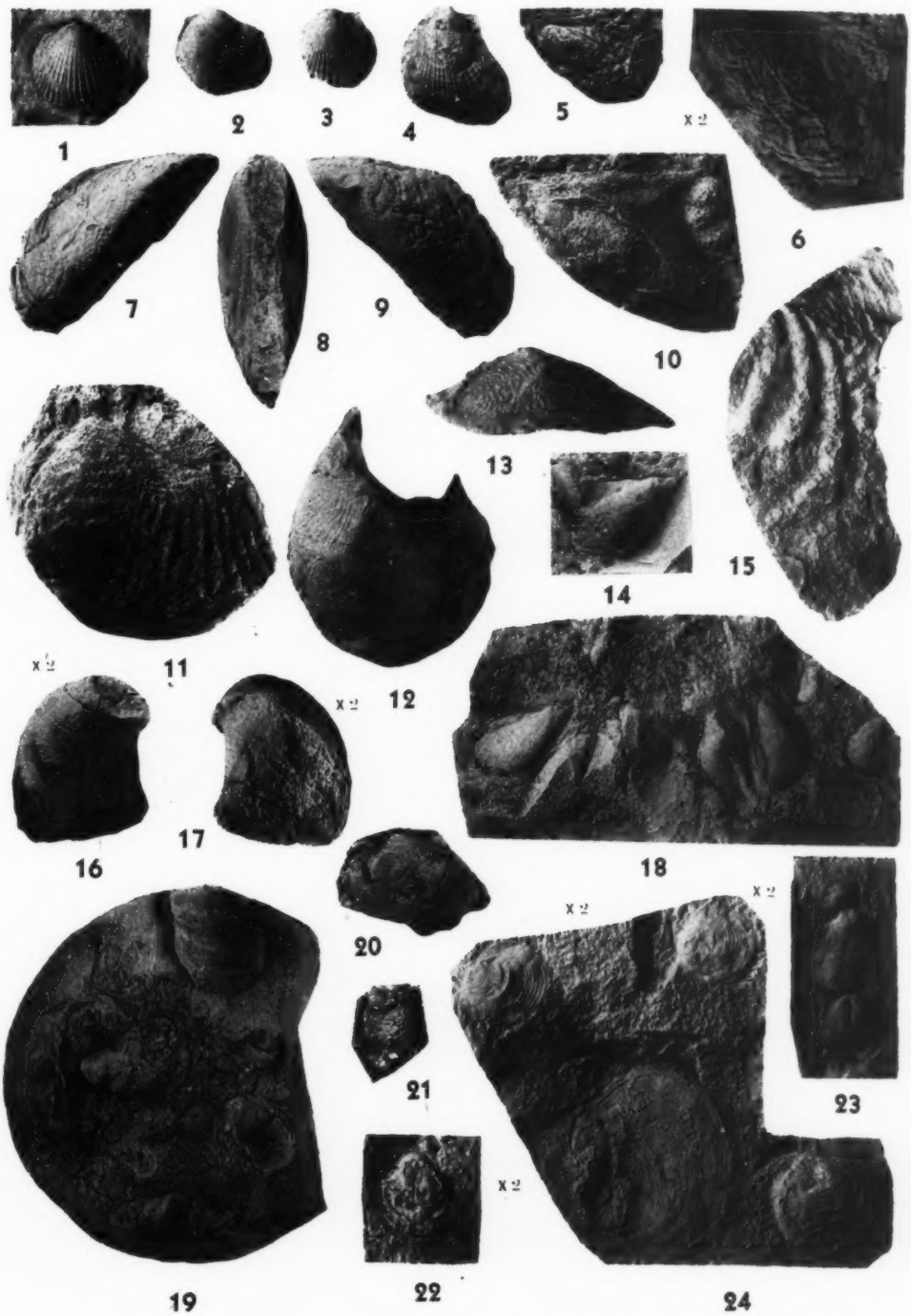
12, 13—Ostrea (*Catinula*) *broughtoni* Imlay, n. sp. Holotype, U. S. Nat. 103628, Cotton Valley formation, Furlong-Clark no. 1 well at depths of 5254–55 feet, ×1. (p. 262)

15—Trigonia aff. *T. vyschetzkii* Cragin. Specimen, U. S. Nat. Mus. 103627, Cotton Valley formation, Union-McDonald no. 1 well at depths of 10822–27 feet, ×1. (p. 262)

16, 17, 19—Exogyra cf. *E. virgula* (Defrance). *16, 17*, Small left valve showing twisted beak, ×2; *19*, left valves showing sculpture, ×1. All specimens, U. S. Nat. Mus. 103629, Cotton Valley formation, Ohio and Gulf-Taylor no 15 well at depths of 9565–66 feet. (p. 262)

20, 21—Aulacomyella sp. Specimens, U. S. Nat. Mus. 103631, Cotton Valley formation, Union-Meadows no. A-1 well at depths of 9888–9908 feet, ×1. (p. 263)

22–24—Posidonia cf. *P. ornati* Quenstedt. All specimens from Smackover limestone of Gulf-Werner no. 49 well. *22*, specimen, U. S. Nat. Mus. 103632 at depth of 6587 feet, ×2; *23*, specimen, U. S. Nat. Mus. 103654 at depth of 6585 feet, ×2; *24*, specimen, U. S. Nat. Mus. 103655 at depth of 6582 feet, ×2. (p. 264)



Imlay, Jurassic Fossils

left valve of the same specimen. Shell small, very inequilateral, elongate, sickle-shaped, convex. Hinge line straight and long, three-fifths the length of the shell. Anterior margin not preserved; posterior margin evenly rounded, merging imperceptibly into the hinge margin, rounding rather abruptly into the ventral margin, which is long and concave. Beak narrow and probably terminal. An elevated carina extends from the beak to the posteroventral region and is preceded anteriorly by a well-developed sulcus. Surface ornamented with rather prominent concentric growth lines and by microscopic radiating lines.

The figured specimen has a length of about 17 mm., a height of 11 mm., and a convexity of 6.5 mm.

Remarks.—Discounting its much smaller size, this species is very similar in all other characters to *Mytilus jurensis* Merian (P. de Loriol, 1872, p. 346, pl. 19, figs. 9, 9a), from the Argovian of Europe. *Mytilus angulatus* Young and Bird (Arkell, 1929, p. 50, pl. 2, figs. 5–7), of Argovian age, is likewise similar but the part of the shell in front of the carina is much larger.

Figured specimen.—U. S. Nat. Mus. 103625.

Occurrence.—Smackover limestone, Union Producing Company's M. M. Waite no. 1 well at depths of 11,803½–15½ feet, sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama.

TABLE 4. COMPARISON OF FOSSILS FROM THE COTTON VALLEY FORMATION

Species from the Cotton Valley formation of the Gulf Region	Similar or identical species elsewhere	Range and occurrence of similar or identical species elsewhere	
Trigonia calderoni (Castillo and Aguilera)	*T. calderoni* (Castillo and Aguilera)	Argovian-Kimmeridgian	Mexico and West Texas
Trigonia cf. *T. vyschetzkii* Cragin	*T. vyschetzkii* Cragin	Kimmeridgian	Mexico and West Texas
Ostrea (*Catinula*) *broughtoni* Imlay, n. sp.	*O. alimena* Cossman	Callovian	Europe
Exogyra cf. *E. virgula* (Defrance)	*E. virgula* (Defrance)	Kimmeridgian	Europe
Pseudomonotis louisianensis Imlay	*P. tamaulipana* Imlay	Kimmeridgian	Mexico
Pseudomonotis durangensis Imlay	*P. durangensis* Imlay	Argovian-Kimmeridgian	Mexico
Aulacomyella sp.	*A. problematica* Furlani	Kimmeridgian	Dalmatia
Astarte breviacola Cragin	*A. breviacola* Cragin	Kimmeridgian	West Texas
Astarte aff. *A. valfinensis* P. de Loriol	*A. valfinensis* P. de Loriol	Kimmeridgian	Europe
Tancredia texana Imlay	*T. astarteformis* Cox	Kimmeridgian	England
Corbicella? cf. *C. laevis* (J. de C. Sowerby)	*C. laevis* (J. de C. Sowerby)	Argovian	England
Metahaploceras cf. *M. nereus* (Fontannes)	*M. nereus* (Fontannes)	Kimmeridgian	Europe
Idoceras cf. *I. durangense* Burckhardt	*I. durangense* Burckhardt	Basal mid. Kimmeridgian	Mexico
Idoceras cf. *I. lorioli* Burckhardt	*I. lorioli* Burckhardt	Basal mid. Kimmeridgian	Mexico
Idoceras cf. *I. complanatum* Burckhardt	*I. complanatum* Burckhardt	Basal mid. Kimmeridgian	Mexico
Glochiceras fialar (Oppel)	*Glochiceras fialar* (Oppel)	Basal mid. Kimmeridgian	Europe and Mexico

Genus TRIGONIA Brugière, 1789

TRIGONIA CALDERONI (Castillo and Aguilera)

Plate 39, figure 11

Goniomya calderoni CASTILLO and AGUILERA, 1895, Com. Geol. México Bol. 1, p. 9, pl. 5, figs. 17, 18.

Trigonia calderoni (Castillo and Aguilera). CRAGIN, 1905, U. S. Geol. Survey Bull. 266, p. 59, pl. 9, figs. 4–6.

Trigonia calderoni (Castillo and Aguilera). IMLAY, 1940, Jour. Paleontology, vol. 14, no. 5, p. 402, pl. 55, fig. 8.

One specimen shows distinctly the ornamentation characteristic of *Trigonia cal-*

deroni. The preareal surface bears subhorizontal ribs anteriorly and nearly vertical ribs posteriorly. The subhorizontal ribs are sigmoidal, are slightly bent upward in the region below the beaks, and are bent downward a little farther back near their junction with the steeply inclined ribs. The margins are poorly preserved.

The presence of this species is of great importance, as it proves the Upper Jurassic age of the Cotton Valley formation and provides a direct correlation with the Upper Jurassic beds of western Texas and northern Mexico.

Plesiotype.—U. S. Nat. Mus. 103626.

Occurrence.—Cotton Valley formation, Union Producing Company's McDonald no. 1 well at depths of 10,822–10,827 feet, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana.

TRIGONIA aff. T. VYSCHETZKII Cragin
Plate 39, figure 15

One fragment of *Trigonia*, occurring in the same core with *T. calderoni* (Castillo and Aguilera) is nearly identical with the medial portion of a left valve figured by Cragin (1905, pl. 8, fig. 2) as *T. vyschetzkii*.

Figured specimen.—U. S. Nat. Mus. 103627.

Occurrence.—Cotton Valley formation, Union Producing Company's McDonald no. 1 well at depths of 10822–10827 feet, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana.

Genus OSTREA Linnaeus, 1758
OSTREA (CATINULA) BROUGHTONI Imlay, n. sp.
Plate 39, figures 12, 13

This species is represented by one fairly well preserved left valve and by a number of imperfect fragments. Shell moderate in size, elongate ovate in outline, elongated obliquely toward the posterior, inequivalve. Left valve highly convex, marked by a large attachment scar; beak small, with a suggestion of a lateral twist; surface ornamented with numerous fine radial ribs and rather strong concentric undulations. The radial ribs are most pronounced on the medial part of the shell and fade toward the ventral margin. A few fragments show that the right valve is nearly flat and is marked only with concentric growth lines.

The figured left valve has a length of 27 mm., a height of 37 mm., and a convexity of 12 mm.

Remarks.—The fine ribbing and the great convexity of the left valve of this species are characteristic of the subgenus *Catinula* Rollier (1911, p. 272; Arkell, 1932, p. 149), which in Europe occurs typically in beds of Bajocian to Callovian age (Arkell, 1933a, pp. 61–63). Of the many described species, *Ostrea* (*Catinula*) *alimena* Cossmann (Arkell, 1933a, p. 54, pl. 5, figs. 1–15), from the Callovian, is probably most similar to the species described herein but has a more incurved beak and coarser, more widely spaced ribs.

Although the oyster from the Cotton Valley formation is represented by only one well-preserved specimen, a new name for it is justified (1) by an ornamentation very different from that of any described species of *Ostrea* in the Jurassic or Lower Cretaceous of North America, and (2) by the occurrence of the most similar European species in beds much older than the Cotton Valley formation.

The species is named in honor of Mr. M. N. Broughton, of The Texas Company, who collected the specimens.

Holotype.—U. S. Nat. Mus. 103628.

Occurrence.—Cotton Valley formation, N. J. Furlong, Jr.,-E. M. Clark no. 1 well at depth of 5254–55 feet, sec. 10, T. 20 N., R. 7 E., Morehouse Parish, Louisiana.

Genus EXOGYRA Say, 1820
EXOGYRA cf. E. VIRGULA (Defrance)
Plate 39, figures 16, 17, 19

Ten fragmentary specimens belong to a finely ribbed species that appears to be identical with *E. virgula* (Defrance), as illustrated by P. de Loriol (1872, p. 397, pl. 23, figs. 8–14) and by Jourdy (1924, p. 68, pl. 5, figs. 1, 8; pl. 6, fig. 4; pl. 8, figs. 9, 10; pl. 9, figs. 17, 18). The left valves are elongate and fairly deep but show considerable variation in shape. Their surfaces are marked by fine radial ribs or striae and by prominent concentric constrictions and swellings. The right valves are flattened or concave and do not show striations. The beaks on the better-preserved specimens have a pronounced lateral twist.

Remarks.—The ornamentation of this

species is highly distinctive for an *Exogyra* and makes it easily recognizable. In Europe, *E. virgula* is characteristic of the middle Kimmeridgian (Havrian or Virgulian) but occurs likewise throughout most of the lower Kimmeridgian (Sequanian), according to the ranges given by Arkell (1933b, pp. 385, 440, 449) and P. de Loriol (1872, p. 399). The occurrence in the lower part of the Cotton Valley formation of Louisiana of an *Exogyra* with the same distinctive ornamentation as *E. virgula* strongly suggests the Kimmeridgian age of that part of the formation. In Mexico, a comparable form has been noted by Burckhardt (1930, pp. 84, 143) as occurring in the Upper Jurassic beds of Sierra de Azul in east-central Coahuila.

Figured specimens.—U. S. Nat. Mus. 103629.

Occurrence.—Cotton Valley formation, Ohio Oil Company's and Gulf Refining Company's G. W. Taylor no. 15 well at the depth of 9565–66 feet, sec. 15, T. 23 N., R. 8 W., Claiborne Parish, Louisiana.

Genus PSEUDOMONOTIS Beyrich, 1862

PSEUDOMONOTIS DURANGENSIS Imlay

Plate 39, figures 1–4

Pseudonomotis durangensis IMLAY, 1940, Jour. Paleontology, vol. 14, no. 5, p. 404, pl. 53, figs. 1–4, 8–10.

The species is represented by many specimens from calcareous sandstones in the lower part of the Cotton Valley formation, where is is associated with small forms of *Corbicella?*, *Exogyra*, and *Ostrea*. It may be distinguished from *Pseudomonotis louisianensis* Imlay (1941, p. 267, pl. 38, figs. 19–23), with which it is associated, by its much coarser, more widely spaced ribs, and by its generally larger size.

Plesiotypes.—U. S. Nat. Mus. 103630a, b, 103674a–c.

Occurrence.—Cotton Valley formation (1) Union Producing Company's Z. J. Meadows no. A-1 well at depths of 9118–9123 feet, sec. 18, T. 21 N., R. 4 W., Claiborne Parish, Louisiana; (2) Phillips Petroleum Company's Kendricks no. 1 well at depths of 6367–6382 and 6488 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana. The species has been recorded in Mexico from the La Gloria and La Casita formations in the mountains west of the Laguna District, eastern Durango.

Genus AULACOMYELLA Furlani, 1910

AULACOMYELLA sp.

Plate 39, figures 20, 21

The species is represented by several crushed, fragmentary specimens. The largest consists of an external mold and an external cast that shows the character of the beak and hinge line. Shell small but probably immature, obliquely ovate, longer than high, inequilateral, compressed. Beaks prominent, projecting over the hinge line, incurved, situated slightly anterior to the middle of the hinge line. Hinge line straight, moderate in length, extending mainly on the posterior side of the beak. Anterior margin semicircular, merging with the hinge line just in front of the beak. Posterior margin longer, less convex, and making a subobtuse angle with the hinge line. Ventral margin not preserved, but, judging from the concentric growth undulations, it is broadly convex. A slight depression or sinus on the posterior margin makes an angle of about 30° with the hinge line and delimits a triangular posterior wing. Surface ornamented by strong concentric growth undulations and by many weak radial ribs. The latter originate a few millimeters from the beak, trend nearly straight to the margins, are of variable size, and are stronger on the posterior than on the anterior side.

Approximate dimensions of specimen figured on pl. 39, fig. 20: Length, 18.5 mm.; height, 14.5 mm.; length of hinge line, 9 mm.

Remarks.—This species differs from *Aulacomyella neogeae* Imlay (1940b, p. 406, pl. 52, figs. 1–6; pl. 53, fig. 26), from the middle Kimmeridgian of Mexico, by its more prominent and more anteriorly situated beak, its shorter hinge line, its more elongate form, and its finer ribbing. It differs from *A. farquharsoni* Cox (1935, p. 167, pl. 15, figs. 9, 10), from the middle Kimmeridgian of British Somaliland, by its much more prominent beak and its less equilateral form. It bears considerable resemblance to *A. problematica* Furlani (1910, pp. 85–88, pl. 3, figs. 2, 3), from the middle Kimmeridgian of Dalmatia, which, however, lacks a sinus in the posterior margin and appears to have a slightly less prominent beak.

The presence of the *Aulacomyella* about 260 feet above the base of the Cotton Valley formation is of considerable stratigraphic significance, as the genus has been recorded only from the middle Kimmeridgian. In Mexico, it is associated with *Glochiceras fialar* (Oppel) and species of the *Idoceras durangense* group (Burckhardt, 1930, pp. 51, 67, 86, 90, 92, 96, 97; Imlay, 1940b, p. 399) that indicate the lower part of the middle Kimmeridgian. In British Somaliland it is associated (Cox, 1935, p. 167; Spath, 1935, pp. 206–209) with *Streblites* and *Waagenia?* sp. ind. that suggest a middle Kimmeridgian age and directly overlies beds containing species of the *Idoceras balderum* group that indicate the top of the lower Kimmeridgian. In Dalmatia it is associated with *Neochetoceras steraspis* (Oppel) and several species of *Metahaploceras* (Furlani, 1910, p. 86, 91) that are typical of the middle Kimmeridgian.

Figured specimens.—U. S. Nat. Mus. 103631.

Occurrence.—Cotton Valley formation, (1) Union Producing Company's Z. J. Meadows no. A-1 well at depths of 9888–9908 feet, sec. 18, T. 21 N., R. 4 W., Claiborne Parish, Louisiana; (2) Phillips Petroleum Company's Kendricks no. 1 well at depths of 7654–64 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

Genus POSIDONIA Bronn, 1828

POSIDONIA cf. P. ORNATI Quenstedt

Plate 39, figures 22–24

The species is represented by about 35 specimens, which preserve the shell but are more or less crushed. Shell fairly small, obliquely ovate, becoming more oblique during growth by extension of the postero-ventral region, longer than high, swollen in the umbonal region, flattened toward the margins, equivalve, inequilateral. Hinge line straight, two-thirds as long as the shell. Ears not distinct. Beaks small, barely projecting beyond hinge line, situated anterior to the middle of the hinge line. Surface ornamented with numerous regular concentric ribs that are fairly strong on the medial and ventral parts of the shell but become indistinct toward the anterior and posterior margins. Interspaces a little wider than ribs.

Remarks.—This form comes within the range of variation of *Posidonia ornati* Quenstedt as figured by Guillaume (1927, p. 222, pl. 10, figs. 4–13). It is as finely ribbed as the Middle Jurassic *P. buchi* (F. A. Roemer) (1836, p. 81, pl. 4, fig. 8; Roemer, J., 1911, p. 14, pl. 1, figs. 15a, b; pl. 2, fig. 1) but is much less elongate. *Posidonia ornati* has been recorded (Guillaume, 1927, p. 225; Weir, 1930, p. 84) from beds of Aalenian, or upper Lias, to Callovian age in many parts of the world, but is particularly abundant in the Middle Jurassic. The genus *Posidonia* is rare in Jurassic beds younger than the Callovian. *Posidonia somaliensis* Cox (1935, p. 166, pl. 15, figs. 7, 8) from the Kimmeridgian of Somaliland, differs from the species described herein by being much larger and nearly equilateral. *Posidonia bononiensis* (P. de Loriol) (1875, p. 170, pl. 21, figs. 3–5), from the Kimmeridgian of France, is similar in size and shape but has much coarser ribbing. *Posidonomya cretacea* Felix (1891, p. 180, pl. 28, figs. 12, 13), from the lower Neocomian of southern Mexico, is almost certainly misidentified generically (Guillaume, 1927, p. 229).

Figured specimens.—U. S. Nat. Mus. 103632, 103654, 103655.

Occurrence.—Smackover limestone, lower member, Gulf Refining Company's Louis Werner Sawmill Company's no. 49 well at depths 6440–6587, sec. 5, T. 16 S., R. 16 W., Union County, Arkansas.

Genus PTEROPERNA Morris and Lycett, 1853

PTEROPERNA? sp.

Plate 39, figures 10, 14, 18

The species is represented by nine specimens, which do not show the characters of the hinge plate. Shell moderately large, elongated obliquely, nearly equivalve, very inequilateral. Hinge long and straight, bearing long posterior and short anterior ears. Anterior margin gently convex, posterior margin concave, ventral margin narrowly but evenly rounded. Beaks small, slightly elevated above the hinge line, not sharply separated from the ears, situated near the anterior end. Surface ornamented with weak concentric growth lines.

Remarks.—This species bears a general resemblance to the Argovian *Pteroperna polyodon* (Buvignier), as figured by Arkell

(1933, p. 201, pl. 25, figs. 6–10), but does not have a prominent posteroventral angle. Its shape is more similar to that of *P. costatula* (Deslongchamps) (Morris and Lycett, 1853, pt. 2, p. 18, pl. 2, figs. 8, 8a, 13, 13a; Cossmann, 1906, p. 8, pl. 2, figs. 6–9), from the Bathonian of Europe, but it lacks the radial ribbing of the latter species.

Figured specimens.—U. S. Nat. Mus. 103633.

Occurrence.—Cotton Valley formation, Union Producing Company's McDonald no. 1 well at depths of 8680–82 feet, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana.

Genus GERVILLIA Defrance, 1820
GERVILLIA aff. G. CORRUGATA Cragin
Plate 39, figures 5, 6

The species is represented by three left valves, of which one shows both internal and external molds. Shell small, fairly convex, inequilateral, obliquely elongated; anterior and posterior margins sigmoidal in outline. Beak small, pointed, curved forward, not projecting beyond hinge line. Anterior wing small, projecting, separated from beak by a slight depression. Posterior wing broad, triangular, strongly projecting, distinctly separated from the body of the shell. Hinge line straight, nearly as long as the greatest antero-posterior diameter, and forming an angle of about 45° with the umbonal ridge.

Surface of the shell ornamented with strong growth lines and radial ribs. The umbones bear numerous radial ribs, but the main body of the shell bears only five or six widely spaced, prominent ribs.

The figured specimen has an estimated length of 16 mm., and height of 12 mm. Another left valve has an estimated length of 20 mm., a height of 14 mm., and a convexity of about 5 mm.

Remarks.—This species has a shape similar to that of *Gervillia corrugata* Cragin (1905, p. 46, pl. 4, figs. 8–10), but has fewer and more widely spaced ribs.

Figured specimen.—U. S. Nat. Mus. 103634.

Occurrence.—Smackover limestone, Union Producing Company's M. M. Waite no. 1 well at depths of 11803½–15½ feet, sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama.

Genus ASTARTE Sowerby, 1817
ASTARTE BREVIACOLA Cragin
Plate 40, figures 1, 2

Astarte breviacola CRAGIN, 1905, U. S. Geol. Survey Bull. 266, p. 64, pl. 11, fig. 4.
Astarte cf. *A. breviacola* CRAGIN. 1941, IMLAY, Jour. Paleontology, vol. 15, no. 3, p. 268, pl. 38, figs. 7, 8.

Several internal molds approach *Astarte breviacola* Cragin even closer than the specimens from the Cotton Valley formation that the writer previously compared with it. They are apparently distinguished from *A. breviacola* by the presence of many fine, concentric striae on both ribs and interspaces, but Cragin's figured type has the shell preserved and cannot be directly compared. Examination of the specimens studied by Cragin shows the presence of striate molds and of specimens as small as those herein figured.

Plesiotypes.—U. S. Nat. Mus. 103635, 103673.

Occurrence.—Cotton Valley formation, (1) Union Producing Company's McDonald no. 1 well at depths of 10,835–10,839, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana; (2) Union Producing Company's Z. J. Meadows no. A-1 well at depths of 9888–9908 feet, sec. 18, T. 21 N., R. 4 W., Claiborne Parish, Louisiana; (3) The Texas Company's T. C. Adams no. C-1 well at depths of 8935–39 and 9006–10 feet, Panola County, Texas; (4) Phillips Petroleum Company's Kendricks no. 1 well at depths of 8279–94 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

ASTARTE GRUBBI Imlay, n. sp.
Plate 40, figures 3, 4

Astarte aff. *A. fimbriata* Walton. IMLAY, 1941, Jour. Paleontology, vol. 15, no. 3, p. 268, pl. 38, figs. 11–13.

The collections in hand contain three specimens of an *Astarte* previously designated *A.* aff. *A. fimbriata*. One of these is much larger and better preserved than the specimens originally figured, and warrants institution of a new species. In addition to the surface features previously described, it shows a distinct and rather deep lunule and a deep elongate escutcheon. These features suggest that the species belongs in the subgenus *Coelastarte*.

Astarte kitchini Cox (1925, p. 149, pl. 1, figs. 11a, b, 12, pl. 4, fig. 8), from the Portlandian of England, has closer-spaced ribbing and more anteriorly situated beaks. *Astarte complanata* Roemer (1836, p. 112, pl. 6, figs. 28a–c), from the Kimmeridgian of Germany, has similarly coarse ribbing, but its beaks are situated more anterior, and its posterodorsal margin is gently convex instead of nearly straight. *Astarte fimbriata* Walton (Lycett, 1863, p. 77, pl. 40, figs. 34, 34a), from the Great Oolite of England, is larger and has closer spaced ribbing. The species is named in honor of C. F. Grubb, of the Carter Oil Company, who collected many fossils from the Smackover formation.

Holotype.—U. S. Nat. Mus. 103636.

Occurrence.—Smackover limestone, (1) Louark Producing Company's Gunnells no. B-2 well at depth of 7490–95 feet, sec. 20, T. 17 S., R. 19 W., Columbia County, Arkansas; (2) Standard Oil Company's Johnson no. B-1 well at depth of 7312–14 feet, sec. 9, T. 16 S., R 22. W., Columbia County, Arkansas; (3) Carter Oil Company's Cornelius no. 2 well at depth of about 9200 feet, sec. 31, T. 17 S., R. 23 W., Lafayette County, Arkansas; (4) Phillips Petroleum Company's J. T. Arnold no. 1 well at depths of 4961–76 feet, sec. 27, T. 15 S., R. 15 W., Ouachita County, Arkansas; (5) Atlantic Refining Company's Levi Garrett no. C-1 well at depth of 747½ feet, sec. 13, T. 17 S., R. 20 W., Columbia County, Arkansas.

ASTARTE aff. A. VALFINENSIS P. de Loriol
Plate 40, figure 9

The species is represented by two specimens. Shell fairly small, subovate, compressed, most inflated above the midheight, inequilateral. Dorsal margins diverge from the beaks at an angle of about 120°. Posterodorsal margin nearly straight, longer than anterodorsal margin, meeting the posterior margin at a subobtuse angle; anterodorsal margin gently concave; anterior, posterior, and ventral margins broadly and evenly rounded. Beaks moderately large and prominent, curved forward, elevated above hinge line, situated slightly in front of the middle of the shell. Surface ornamented with about 25 moderately high, narrow, concentric ribs, which are strongest in the medial part of the shell. Length, 8.5 mm.; height, 8 mm.

Remarks.—This species is remarkably similar to *Astarte valfinensis* P. de Loriol (1888, p. 279, pl. 32, figs. 3–3c), from the Kimmeridgian of Switzerland, but possibly has more prominent beaks.

Figured specimen.—U. S. Nat. Mus. 103637.

Occurrence.—Cotton Valley formation, Union Producing Company's McDonald no. 1 well at depths of 10,959–10,969 feet, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana.

ASTARTE (COELASTARTE) cf. A. RATHIERI P. de Loriol
Plate 40, figures 5, 6, 10, 11

This species is represented by nine specimens. Shell fairly compressed, elongate, subrectangular in outline, inequilateral. Posterodorsal margin long and nearly straight; anterodorsal margin short and concave; anterior margin short and rounded; posterior margin nearly straight, nearly vertical, meeting the posterodorsal margin at a subobtuse angle; ventral margin long, nearly straight, rounding evenly into anterior margin and abruptly into posterior margin. Beaks small, compressed, curved inward and forward, not elevated above hinge line, situated about one-sixth the length of the shell from the anterior end. A low ridge extends obliquely from the beak to the posteroventral angle and is paralleled anteriorly by a faint depression.

Surface ornamented by 8 to 13 elevated, narrowly rounded, concentric ribs, which are finest near the anterior margin, coarsest on the oblique ridge, and are angulated where they cross the ridge. Interspaces broadly rounded, in most places about three times as wide as the ribs.

The specimen figured on plate 40, figure 6 (left side), has a length of 7.5 mm., and a height of 4.5 mm. Some of the specimens are half again as large.

Remarks.—The only described American species bearing much resemblance to this species is *Astarte* (*Coelastarte*) *hazzardi* Imlay (1941, p. 269, pl. 38, figs. 37, 38), from the upper part of the Smackover limestone. The

latter species is much more elongate, has more anteriorly situated beaks, and has closer spaced ribbing. *Astarte interlineata* Lycett (Morris and Lycett, 1853, p. 87, pl. 9. figs. 14, 15a, b), from the Middle Jurassic of England, has a more rectangular shape and sparser ribbing. *Astarte rathieri* P. de Loriol (1893, p. 107, pl. 8, figs. 2, 3), from the lower Kimmeridgian of France, is strikingly similar but apparently has a more rectangular outline.

Figured specimens.—U. S. Nat. Mus. 103638–103640.

Occurrence.—Smackover limestone, Union Producing Company's M. M. Waite no. 1 well at depths of 11,803½–15½, 11,958–60, 12,004–07, 12,079–83 feet, sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama.

TRAPEZIUM? cf. T.? SUBTRIGONUM Imlay
Plate 40, figure 7

One small specimen from the Buckner formation is probably an immature form of *Trapezium? subtrigonum* Imlay (1941, p. 270, pl. 38, fig. 41), from the lower part of the Cotton Valley formation of Louisiana. Its anterior margin is a little more broadly rounded, and its ventral margin more convex, but these may be only growth differences.

Figured specimen.—U. S. Nat. Mus. 103641.

Occurrence.—Buckner formation, Union Producing Company's M. M. Waite no. 1 well at depth of 11,669–71 feet, sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama.

Genus CORBICELLA Morris and Lycett, 1854

CORBICELLA? cf. C. LAEVIS
(J. de C. Sowerby)
Plate 40, figure 12

The species is represented by one internal mold of a right valve. Shell elongate trigonal compressed. Beak elevated, small, situated slightly anterior to the medial part of the shell. Posterodorsal margin nearly straight; anterodorsal margin concave; posterior margin evenly rounded; anterior margin rather sharply rounded; ventral margin broadly convex. Surface ornamented with concentric lines of growth. Dimensions: Length, 28 mm.; height, 21 mm.; convexity, 2 mm.

Remarks.—This species has an outline almost identical with that of *Corbicella laevis* (J. de C. Sowerby) (1827, p. 156, pl. 580; Arkell, 1934, p. 289, pl. 39, figs. 1–5), from the Argovian of England, but is much thinner. It is more trigonal in outline and much more compressed than the *Corbicella?* sp. described below. Both species are strongly suggestive of *Corbicella* rather than *Tancredia* or *Quenstedtia*. *Tancredia* is distinguished by a more acute anterior end, generally an obliquely truncated posterior end, and a pronounced posterior gape. *Quenstedtia* is more elongate posteriorly.

Figured specimen.—U. S. Nat. Mus. 103642.

Occurrence.—Cotton Valley formation, R. W. Norton-John E. Payne no. 1 well at depths of 9406–21 feet, sec. 27, T. 23 N., R. 16 W., Caddo Parish, Louisiana.

CORBICELLA? sp.
Plate 40, figure 8

The species is represented by one internal mold of a left valve. Shell elongate-ovate and moderately convex. Beak fairly prominent, situated slightly anterior to the medial part of the shell. Dorsal margins sloping from the beak at an angle of about 140°; posterodorsal margin nearly straight; anterodorsal margin slightly convex; posterior margin broadly rounded; anterior margin more narrowly rounded; ventral margin gently rounded, surface marked with concentric lines of growth. Dimensions: Length, 21 mm.; height, 15 mm.; convexity, 3 mm.

Remarks.—This species resembles *Corbicella subaequilatera* Lycett (1863, p. 69, pl. 35, fig. 12), from the upper Bathonian of England, in outline and prominence of the umbonal region but appears to have a more medially situated beak. It also bears a general resemblance to *C. eboracensis* Arkell (1934, p. 290, pl. 39, figs. 6–8), from the Argovian of England.

Figured specimen.—U. S. Nat. Mus. 103643.

Occurrence.—Cotton Valley formation, Union Producing Company's Z. J. Meadows no. A-1 well at depths of 8997–9002 feet, sec. 18, T. 21 N., R. 4 W., Claiborne Parish, Louisiana.

Genus QUENSTEDTIA Morris and Lycett, 1854

QUENSTEDTIA WEEKSI Imlay

Plate 40, figures 13–15

Quenstedtia weeksi IMLAY, 1941, Jour. Paleontology, vol. 15, no. 3, p. 272, pl. 38, figs. 18, 24, 25.

This species was found in abundance associated with *Quenstedtia spearsi* Imlay, in a 6-inch core of black calcareous, silty shale from the middle part of the Buckner formation. The occurrence is noteworthy, as the shales of the Buckner formation are almost invariably red or green and have not hitherto yielded marine fossils. The specimens illustrated agree with the types in all details, except in size, but fragmentary specimens in the core are as large as the types.

Plesiotype.—U. S. Nat. Mus. 103644.

Occurrence.—Buckner formation, Union Producing Company's McDonald no. 1 well at depths of 11,661–63 feet, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, Louisiana.

QUENSTEDTIA SPEARSI Imlay, n. sp.

Plate 40, figures 16–18, 24

The species is represented by numerous specimens intimately associated with *Quenstedtia weeksi* Imlay in a 6-inch core. Shell very small for genus, compressed, elongate-trigonal in outline, very inequilateral. Anterior end much shorter than the posterior end. Anterodorsal margin much shorter and steeper than posterodorsal margin; anterior margin moderately wide, rounding rather abruptly into anterodorsal margin and fairly rapidly into ventral margin; posterior margin steeply inclined, a little wider than anterior margin, meeting dorsal margin at a subobtuse angle, meeting ventral margin at nearly a right angle; ventral margin gently convex. Beaks flattened, projecting distinctly above the hinge line, about one-third the length of the shell from the anterior end. A distinct, elevated ridge trends from the umbo to the posteroventral angle. Surface ornamented with concentric growth lines.

Dimensions are as follows: holotype, length 13 mm., height 7.5 mm.; paratypes a–c, lengths 7, 8.5, and 9 mm.; height, 4, 5, and 5 mm.

Remarks.—This species is placed in *Quenstedtia* rather than *Corbicella*, because of its greatly elongated posterior end, but its shape is more trigonal than any species of *Quenstedtia* known to the writer. Compared with *Q. weeksi* Imlay it has a more trigonal shape, more elevated beaks, and a distinct ridge on its posterior slope. A similar ridge has been noted on several species of *Quenstedtia* and *Corbicella*. Among these, *Corbicella? moreana* (Buvignier) (1852, p. 46, in Atlas, pl. 4, figs. 9, 10; Loriol, 1868, p. 566, pl. 9, fig. 7), from the upper Kimmeridgian and Portlandian of Europe, may be distinguished by its less anteriorly situated beaks. *Quenstedtia portlandica* Cox (1929a, p. 191, pl. 6, figs. 5, 6), from the Portlandian of England, has a subrectangular outline.

The species is named in honor of Mr. W. H. Spears of the Union Producing Company at Shreveport, Louisiana.

Types.—Holotype, U. S. Nat. Mus. 103645; 3 figured paratypes, U. S. Nat. Mus. 103646; 4 nonfigured paratypes, U. S. Nat. Mus. 103647.

Occurrence.—Buckner formation, Union Producing Company's McDonald no. 1 well at depths of 11,661–63 feet, sec. 13, T. 21N., R. 5 W., Claiborne Parish, Louisiana.

Genus PHOLADOMYA G. B. Sowerby, 1825

PHOLADOMYA cf. P. HEMICARDIA Roemer

Plate 40, figures 22, 23, 25, 28, 29

The species is represented by seven specimens, of which most are rather strongly distorted. Shell small, inflated, shape elongate-ovate but highly variable, gaping posteriorly. Anterior margin truncate, posterior margin evenly rounded, ventral margin very convex. Hinge line long and nearly straight. Umbones prominent. Surface ornamented with conspicuous concentric growth lines and with about seven fine, widely spaced radial ribs that occur on all parts of the shell.

The figured specimen has a length of 24 mm., a height of 17 mm., and a convexity of 15.5 mm.

Remarks.—This species agrees in character of ribbing, length of hinge line, and range of form with *Pholadomya hemicardia* Roemer (1836, p. 131, pl. 9, figs. 18a, b; P. de Loriol, 1872, p. 178, pl. 11, figs. 5–8; Moesch, 1874, p. 58, pl. 23, figs. 1–6; pl. 24, fig. 11; Arkell, 1935, p. 336, pl. 46, figs. 5–7), from the Argovian and Kimmeridgian of Europe.

The figured specimen of *Pholadomya marcoui* Cragin (1905, p. 80, pl. 16, figs. 1, 2) appears to have a less truncate anterior margin, a more gently convex ventral margin, and less elevated beaks, but some of the specimens of *P. marcoui* studied by Cragin cannot be distinguished from the species herein described. *Pholadomya protei* (Brongniart) (equals *P. paucicosta* Roemer, 1836, p. 131, pl. 16, fig. 1; Moesch, 1874, p. 76, pl. 25, fig. 18; pl. 26, figs. 6, 7; pls. 27, 28, 29; Arkell, 1935, p. 333, pl. 46, figs. 8, 9; pl. 47, figs. 1–4) has a shorter hinge line and fewer ribs that do not occur on the anterior and posterior parts of the shell.

Figured specimen.—U. S. Nat. Mus. 103648.

Occurrence.—Smackover limestone, Union Producing Company's M. M. Waite no. 1 well at depths of 11,803½–15½ and 11,940–43 feet, sec. 27, T. 8 N., R 1 W., Clarke County, Alabama.

Genus PURPURINA d'Orbigny, 1850

PURPURINA (EUCYCLOIDEA?) sp.

One fragmentary external mold shows five whorls of the spire. Shell conical, turreted. Whorls angular and bearing a prominent serrated keel about two-thirds of the distance from the posterior margin. Serrations on keels strong and regularly spaced. Surface of shell ornamented with many fine spiral ribs and with faint but broad vertical ribs.

This species might be placed in *Purpurina* (*Pseudalaria*) Hudleston (1888, p. 188) except for the presence of faint vertical ribbing and strongly serrated keels. It bears considerable resemblance to *P. belia* d'Orbigny (1853, pl. 330, figs. 9, 10), from the Middle Jurassic of France, but its keels are situated lower on the whorls.

Specimen.—U. S. Nat. Mus. 103649.

Occurrence.—Smackover limestone, Barnsdall Oil Company's Bond no. 1 well at depth of 6352–62 feet, sec. 11, T. 15 S., R 24 W., Lafayette County, Arkansas.

Genus PHANEROPTYXIS Cossmann, 1896

PHANEROPTYXIS ANGULATA Imlay

Plate 40, figures 19–21, 26, 27, 30, 31

Phaneroptyxis? angulata IMLAY, 1941, Jour. Paleontology, vol. 15, no. 3, p. 274, pl. 39, figs. 14–16.

This species is now known by seven specimens in addition to the two previously figured types. These specimens show that the axial ribs vary somewhat in strength on the spire and disappear on the last whorl of the adult form. Similar variation in ribbing occurs on *P. moreana* (d'Orbigny) (1851, p. 100, pl. 257, figs. 1, 2; Buvignier, 1852, p. 35, pl. 24, figs. 10–12; Schlosser, 1881, p. 82, pl. 5, figs. 2, 3; P. de Loriol, 1893, p. 23, pl. 2, fig. 5; Cossmann, 1898, p. 14, pl. 2, figs. 1, 2). The larger specimen figured by Schlosser (1881, pl. 5, fig. 2) has a smooth body whorl like the form shown on pl. 40, fig. 21. *Phaneroptyxis angulata* may be distinguished from *P. moreana* by its more steplike spire, more prominent axial ribbing on the early whorls, and somewhat higher whorls, but the resemblances are very great.

Plesiotypes.—U. S. Nat. Mus. 103650, 103656.

Occurrence.—Smackover limestone, (1) Louark Producing Company's Gunnels no. B-2 well at depth of 7490–95 feet, sec. 20, T. 17 S., R. 19 W., Columbia County, Arkansas; (2) Barnsdall Oil Company's Dobson no. 1 well at depth of 6429–30 feet, sec. 10, T. 15 S., R. 24 W., Lafayette County, Arkansas; (3) Barnsdall Oil Company's Bond no. 1 well at depth of 6317–32 feet, sec. 11, T. 15 S., R 24 W., Lafayette County, Arkansas; (4) Phillips Petroleum Company's Arnold no. 1 well at depth of 4946–56 feet, sec. 27, T. 15 S., R. 15 W., Ouachita County, Arkansas.

Genus NERINEA Defrance, 1825

NERINA cf. N. TURBATRIX P. de Loriol

Plate 41, figure 1

Nerinea cf. *N. turbatrix* P. de Loriol. IMLAY, 1941, Jour. Paleontology, vol. 15, no. 3, p. 275, pl. 39, figs. 17–20.

One specimen, represented by an external mold and part of an internal mold is, more complete than the specimens previously figured. It consists of nine whorls, which become decidedly less concave anteriorly.

Figured specimen.—U. S. Nat. Mus. 103651.

Occurrence.—Smackover limestone, Standard Oil Company of Louisiana Johnson no. B-1 well at depth of 7281 feet, sec. 9, T. 16 S., R. 22 W., Colombia County, Arkansas.

NERINEA? LAFAYETTENSIS Imlay, n. sp.
Plate 41, figures 4, 5

The species is represented by one external mold of the spire. Shell turreted, attenuated, apical angle about 11°. Sixteen whorls preserved. Last whorl, apparently the body whorl, bears a sharp carina at its base. Whorls twice as wide as high, very concave, bearing a prominent sutural ridge. Suture distinct, situated slightly posterior to the most elevated part of the sutural ridge. Whorls ornamented with four weak spiral ribs, of which one marks the anterior margin of the whorl, and one marks the summit of the sutural ridge. The other two ribs occur in the concave part of the whorl and are closer to each other than to the marginal ribs. The lowermost three whorls show faint spiral lines between the main ribs. Growth lines not visible.

Remarks.—This species is readily distinguishable from *Nerinea goodellii* Cragin (1905, p. 96, pl. 21, figs. 1–3) by the suture's not occurring at the summit of the sutural ridge. *Nerinea* aff. *N. goodellii* Cragin, as described by Imlay (1941, p. 275, pl. 39, fig. 10), has less prominent sutural ridges and more spiral lines at comparable growth stages. *Aptyxiella saemanni* (P. de Loriol) (1866, p. 24, pl. 3, figs. 8–10; Cossmann, 1898, p. 151, pl. 11, figs. 16–18), from the upper Kimmeridgian of France, is somewhat similar, but its whorls are apparently less concave, its suture is situated at the summit of the sutural ridge, and its whorls are narrower.

Holotype.—U. S. Nat. Mus. 103652.

Occurrence.—Smackover limestone, Barnsdall Oil Company's Bond no. 1 well at depths of 6352–62 feet, sec. 11, T. 15 S., R. 24 W., Lafayette County, Arkansas.

NERINEA? HELICATA Imlay, n. sp.
Plate 41, figure 6.

One external mold has a form unlike any genus known to the writer but showing some similarity to the Nerineidae. Shell turreted, attenuated, apical angle about 15°. Only three whorls preserved. Whorls about three-fifths as wide as high; elevated a little below the middle into a prominent, narrowly rounded ridge that separates the whorl into a deep anterior concavity, and a much shallower posterior concavity; elevated at their margins into prominent, rather broadly rounded sutural ridges. Suture closely appressed, steeply inclined, situated on the anterior part of the sutural ridge. Last whorl concave below the sutural ridge. Surface smooth except for lines of growth.

Remarks.—Regardless of its generic position, this species should be easily recognized by its steeply inclined suture and the division of each whorl into two concave areas by a submedian ridge.

Holotype.—U. S. Nat. Mus. 103653.

Occurrence.—Smackover limestone, Normandie Oil Corp.-Crumpler no. B-1 well at depth of 7518 feet, sec. 18, T. 17 S., R. 19 W., Columbia County, Arkansas.

Genus APTYXIELLA P. Fischer, 1885
APTYXIELLA (NERINOIDES)? aff.
A. STANTONI (Cragin)
Plate 41, figures 2, 3

The species is represented by one external mold. Shell turreted, attenuated, apical angle about 10°. Whorls 20 or more, about 1½ times as wide as high, concave. Suture closely appressed, situated on a low ridge. Whorls on upper part of spire ornamented with five strong spiral ribs that are nearly equally spaced. Whorls on lower part of spire ornamented with six ribs, of which the most anterior rib is rather indistinct. Height (incomplete), 24 mm., diameter, 3.5 mm.

Remarks.—This species is associated in the same piece of limestone with *Xystrella?* aff. *X. papillosa* (Deslongchamps), *Cryptoptyxis? diversicostata* Imlay, *Astarte* aff. *A. fimbriata* Walton, and *Thamnasteria imlayi* Wells. It is readily distinguished from *Nerinea goodellii* Cragin (1905, p. 96, pl. 21, figs. 1–3) by its less pronounced sutural ridges, much coarser and fewer ribs, and a smaller apical angle. *Aptyxiella* (*Nerinoides*) *stantoni* (Cragin) (1905, p. 98, pl. 21, figs. 6–9) has similar ornamentation but is more elongate. *Aptyxiella* (*Nerinoides*) *aciculus* (d'Archiac) (d'Orbigny, 1851, p. 91, pl. 253, figs. 10, 11) from the Bathonian of France appears to be very similar in all respects.

Figured specimen.—U. S. Nat. Mus. 103657.

Occurrence.—Smackover limestone, Carter Oil Company's Cornelius no. 2 well at depth of about 9200 feet, sec. 31, T. 17 S., R. 23 W., Lafayette County, Arkansas.

Genus METAHAPLOCERAS Spath, 1925

METAHAPLOCERAS cf. M. NEREUS (Fontannes)

Plate 41, figure 19

One partly crushed specimen is represented by both external and internal molds, of which the latter retains considerable shell material. The ornamentation consists of falciform striae on the lower two-thirds of the flanks and of striated, variably strong folds on the upper third of the flanks. The striae incline forward on the umbilical wall, curve gently backward just above the umbilical wall, then curve forward strongly to a place slightly below the middle of the flanks, and then recurve strongly to the upper third of the flanks, where they pass into folds. The folds incline forward strongly on the flanks, cross the venter with a gentle forward arching, and are most swollen on the ventrolateral margins, between which they are much reduced.

Remarks.—The ornamentation of this specimen appears to be nearly identical with that of a variety of *Metahaploceras nereus* (Fontannes) (1879, p. 39, pl. 5, fig. 5), from the lower and middle Kimmeridgian of Europe. Its ribbing is stronger and more falciform than that of the specimen described by Burckhardt (1906, p. 76, pl. 16, figs. 5–7) as *Oppelia* (*Neumayria*) cf. O. *nereus* Fontannes, from the middle Kimmeridgian of Mexico.

Figured specimen.—U. S. Nat. Mus. 103661.

Occurrence.—Cotton Valley formation, Phillips Petroleum Company's Kendricks no. 1 well at depths of 7654–64 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

Genus GLOCHICERAS Hyatt, 1900

GLOCHICERAS FIALAR (Oppel) of Burckhardt

Plate 41, figure 20

Haploceras mazapilense CASTILLO and AGUILERA, 1895, Com. Geol. México Bol. 1, p. 20, pl. 7, fig. 4.

?Haploceras carinatum CASTILLO and AGUILERA, 1895, idem, p. 19, pl. 7, fig. 6.

Halpoceras fialar Oppel sp. BURCKHARDT, 1906, Inst. Geol. México Bol. 23, p. 77, pl. 19, figs. 1–19; pl. 20, figs. 1–6, 12, 14, 15.

Haploceras fialar Oppel. BURCKHARDT, 1930, Schweizer. palaeont. Gesell. Abh., Band 49, p. 49.

Glochiceras fialar Buckhardt (not Oppel). IMLAY, 1939, Geol. Soc. Amer. Bull., vol. 50, p. 26.

One specimen, represented by both external and internal molds retaining some shell material, is identical with the common Mexican species which Burckhardt referred to *Haploceras fialar* Oppel. The specimen is characterized by the early development of a strong spiral furrow and of falciform striae and folds. It is slightly compressed but has a maximum diameter of 22 mm., an umbilical width of 5 mm., and a whorl height of 9 mm.

Figured specimen.—U. S. Nat. Mus. 103662.

Occurrence.—Cotton Valley formation, Phillips Petroleum Company's Kendricks no. 1 well at depths of 8048–63 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

Genus IDOCERAS Burckhardt, 1906

IDOCERAS cf. I. COMPLANATUM Burckhardt

Plate 41, figures 18, 22

Fourteen fragments resemble the outer whorl of *I. complanatum* Burckhardt (1912, p. 115, pl. 28, figs. 4, 6–8). The primary ribs are weakened near the middle of the flanks. Some remain simple, but the majority branch a little above the middle into two or three secondary ribs, which are narrow, fairly prominent, and incline strongly forward. One constriction is present.

Figured specimens.—U. S. Nat. Mus. 103663a, b.

Occurrence.—Cotton Valley formation, Phillips Petroleum Company's Kendricks no. 1 well at depths of 8048–63 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

IDOCERAS cf. I. DURANGENSE Burckhardt

Plate 41, figure 23

One crushed specimen shows parts of three whorls, of which the larger has been partly displaced from the next inner whorl. The two inner whorls bear strong, straight, forwardly inclined ribs, of which most bifurcate a little above the middle of the flanks. The outer whorl bears slightly flexuous, primary ribs, which are much weakened in the middle of the flanks and divide on the upper third into two or three stronger but narrower secondary ribs. The latter incline

backward near their points of origin and then strongly forward.

Remarks.—This species is probably identical with *I. durangense* Burckhardt (1912, p. 107, pl. 26, figs. 1–6; pl. 27, figs. 1, 2). The only other comparable described species is *I. tuttlei* Burckhardt (1912, p. 109, pl. 27, figs. 3–6), which has much stronger and more widely spaced ribbing.

Figured specimen.—U. S. Nat. Mus. 103664.

Occurrence.—Cotton Valley formation, Phillips Petroleum Company's Kendricks no. 1 well at depths of 8048–63 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

IDOCERAS cf. I. LORIOLI Burckhardt
Plate 41, figure 21

One fragment of an outer whorl resembles *Idoceras lorioli* Burckhardt (1912, p. 109, pl. 28, figs. 1–3, 5) in the nearly complete disappearance of the primary ribs from the middle of the flanks, in the prominence of the secondary ribs on the upper part of the flanks, and in the presence of a large, pronounced constriction.

Figured specimen.—U. S. Nat. Mus. 103665.

Occurrence.—Cotton Valley formation, Phillips Petroleum Company's Kendricks no. 1 well at depths of 8048–63 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

IDOCERAS (SUBNEBRODITES)? sp.
Plate 41, figure 15

One small fragmentary ammonite has prominent bifurcating ribs alternating with intercalary ribs in a manner suggestive of the earliest strongly evolute forms of *Idoceras*, which have been called *Subnebrodites* by Spath (1925, p. 129). Its ribbing is particularly suggestive of one of the small forms assigned by Quenstedt (1888, p. 974, pl. 108, fig. 8) to *Ammonites planula* (Hehl) Zieten, the type of *Subnebrodites*. The reference to *Idoceras* (*Subnebrodites*) may be cor-

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EXPLANATION OF PLATE 40

FIGS. *1, 2*—*Astarte breviacola* Cragin. *1*, Plesiotype, U. S. Nat. Mus. 103635, Cotton Valley formation, Union-McDonald no. 1 well at depths of 10835–39 feet, ×2; *2*, plesiotype, U. S. Nat. Mus. 103673, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 8279–94 feet, ×3. (p. 265)

3, 4—*Astarte grubbi* Imlay, n. sp. Lateral and dorsal views of holotype, U. S. Nat. Mus. 103636, Smackover limestone, Carter-Cornelius no. 2 well at depth of 9200 feet, ×3. (p. 265)

5, 6, 10, 11—*Astarte* (*Coelastarte*) cf. *A. rathieri* P. de Loriol. All specimens from Smackover limestone of Union-Waite no. 1 well. *5*, specimen, U. S. Nat. Mus. 103638a at depth of 11803½–15½, ×2; *6*, specimen, U. S. Nat. Mus. 103639 at depths of 11958–60 feet, ×1; *10*, specimen, U. S. Nat. Mus. 103638b at depths of 11803½–15½ feet, ×1; *11*, specimen, U. S. Nat. Mus. 103640 at depths of 12004–07 feet, ×2. (p. 266)

7—*Trapezium?* cf. *T. subtrigonum* Imlay. Specimen, U. S. Nat. Mus. 103641, Buckner formation, Union-Waite no. 1 well at depth of 11669–71 feet, ×1. (p. 267)

8—*Corbicella?* sp. Specimen, U. S. Nat. Mus. 103643, Cotton Valley formation, Union-Meadows no. A-1 well at depth of 8997–9002 feet, ×1. (p. 267)

9—*Astarte* aff. *A. valfinensis* P. de Loriol. Specimen, U. S. Nat. Mus. 103637, Cotton Valley formation, Union McDonald no. 1 well at depths of 10963–69 feet, ×1. (p. 266)

12—*Corbicella* cf. *C. laevis* (J. de C. Sowerby). Specimen, U. S. Nat. Mus. 103642, Cotton Valley formation, Norton-Payne no. 1 well at depth of 9406–21 feet, ×1. (p. 267)

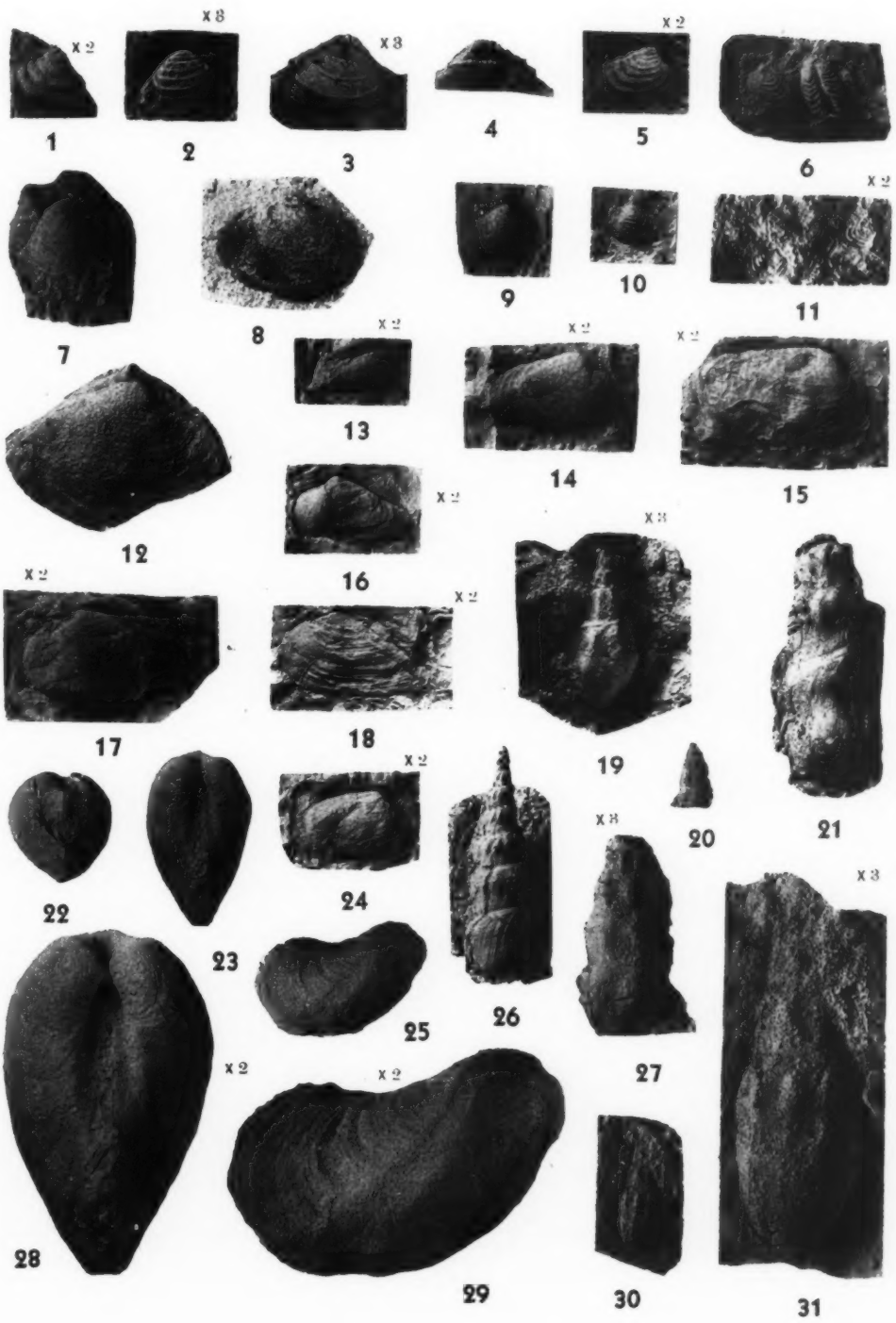
13–15—*Quenstedtia weeksi* Imlay. Plesiotypes, U. S. Nat. Mus. 103644, Buckner formation, Union-McDonald no. 1 well at depths of 11661–63 feet, ×2. (p. 268)

16–18, 24—*Quenstedtia spearsi* Imlay, n. sp. All specimens from Buckner formation of Union-McDonald no. 1 well at depth of 11661–63 feet, ×2; *16, 18, 24*, paratypes, U. S. Nat. Mus. 103646; *17*, holotype, U. S. Nat. Mus. 103645. (p. 268)

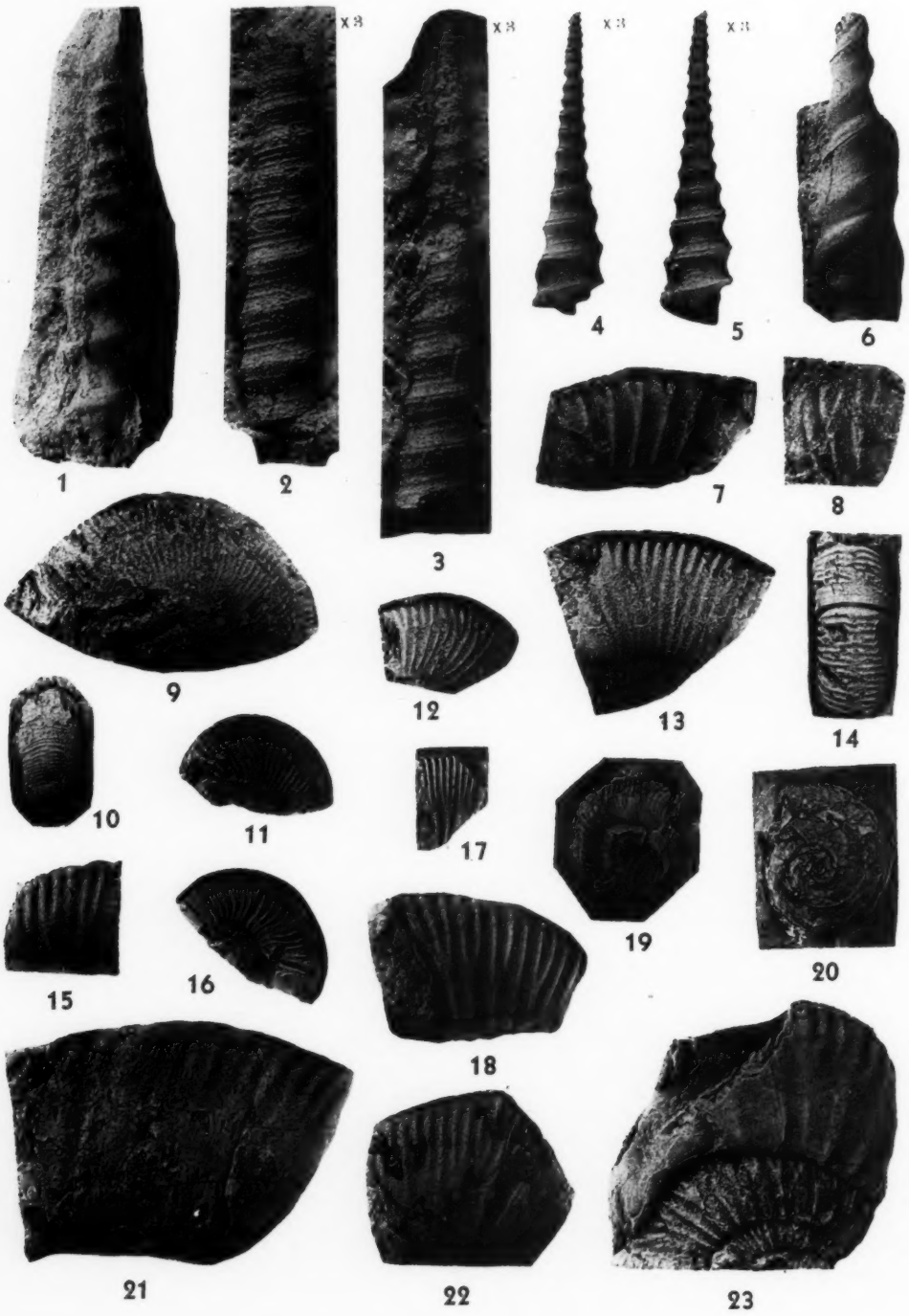
19–21, 26, 27, 30, 31—*Phaneroptyxis angulata* Imlay. *19–21, 27, 30, 31* represent plesiotypes, U. S. Nat. Mus. 103650, Smackover limestone, Louark-Gunnels no. B-2 well at depths of 7490–95 feet, ×3 and ×1; *26*, plesiotype, U. S. Nat. Mus. 103656, Smackover limestone, Barndall-Dobson no. 1 well at depths of 6429–30 feet, ×1. Note that fig. *27* is an enlargement of fig. *20*, and fig. *31* is an enlargement of fig. *30*. (p. 269)

22, 23, 25, 28, 29—*Pholadomya* cf. *P. hemicardia* Roemer. Anterior, dorsal, and lateral views of specimens, U. S. Nat. Mus. 103648, Smackover limestone, Union-Waite no. 1 well at depths of 11803½–15½ feet, ×1 and ×3. (p. 268)

3, 4, 19–21, 26, 27, 30 and *31* are from rubber casts of external molds.



Imlay, Jurassic Fossils



Imlay, Jurassic Fossils

rect, as the fragment is associated with *Ataxioceras* about 300 feet below beds containing *Glochiceras fialar* (Oppel) of Burckhardt and *Idoceras* of the group of *I. durangense* Burckhardt.

Figured specimen.—U. S. Nat. Mus. 103666.

Occurrence.—Cotton Valley formation (probable marine equivalents of the Buckner formation), Phillips Petroleum Company's Kendricks no. 1 well at depths of 8377–92 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

Genus ATAXIOCERAS Fontannes, 1879

ATAXIOCERAS sp.

Plate 41, figures 16, 17

Several fragments show the rib-branching characteristic of *Ataxioceras*. The figured specimens have been so crushed laterally that their flanks appear to be much wider and flatter than they originally were. The immature form illustrated on plate 41, figure 16, has a fairly narrow umbilicus. It is ornamented with many fine, sharp, prorsiradiate, slightly flexuous ribs and with three rather pronounced constrictions. The primary ribs are inflected gently forward and attain their greatest prominence just below the middle of the flanks. Most of them bifurcate near the middle of the flanks, and one of the branches bifurcates again at a slightly higher level. A few primary ribs bifurcate below the middle of the flanks, and both branches bifurcate again on the upper third of the flanks. The secondary ribs are rounded, equally spaced, strongest on the venter, and many of them rather obscurely connected with the primary ribs. Interspaces are from two to four times as wide as the primary ribs, and only slightly wider than the secondary ribs. A more mature form illustrated on plate 41, figure 17, shows both biplicate and triplicate ribbing, and its secondary branches are nearly as sharp as its primary ribs.

Remarks.—The specimens from Louisiana are so much smaller than most illustrated forms of *Ataxioceras* that comparisons are difficult, but the combination of sharp,

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EXPLANATION OF PLATE 41

FIGS. 1—*Nerinea* cf. *N. turbatrix* P. de Loriol. Specimen, U. S. Nat. Mus. 103651, Smackover limestone, Standard Oil of Louisiana-Johnson no. B-1 well at depth of 7281 feet, ×1. (p. 269)

2, 3—*Aptyxiella* (*Nerinoides*)*?* aff. *A. stantoni* Cragin. Specimen, U. S. Nat. Mus. 103657, Smackover limestone, Carter-Cornelius no. 2 well at depth of about 9200 feet, ×3. (p. 270)

4, 5—*Nerinea? lafayettensis* Imlay, n. sp. Holotype, U. S. Nat. Mus. 103652, Smackover limestone, Barnsdall-Bond no. 1 well at depths of 6352–62 feet, ×3. (p. 270)

6—*Nerinea? helicata* Imlay, n. sp. Holotype, U. S. Nat. Mus. 103653, Smackover limestone, Normandie Oil Corp.-Crumpler no. B-1 well at depth of 7518 feet, ×1. (p. 270)

7, 8—*Dichotomosphinctes?* sp. Specimens, U. S. Nat. Mus. 103670, Smackover formation, Phillips-Kenricks no. 1 well at depths of 8741–56 feet, ×1. (p. 274)

9–11—*Discosphinctes* cf. *D. virgulatus* (Quenstedt) of Burckhardt. Lateral and ventral views of specimens, U. S. Nat. Mus. 103671, Smackover formation, Phillips-Kendricks no. 1 well at depths of 8741–56 feet, ×1. (p. 274)

12–14—*Discosphinctes?* cf. *D. lucingensis* (Choffat) of Burckhardt. Lateral and ventral views of specimens, U. S. Nat. Mus. 103672, Smackover formation, Phillips-Kenrdicks no. 1 well at depths of 8741–56 feet, ×1. (p. 274)

15—*Idoceras* (*Subnebrodites*)*?* sp. Specimen, U. S. Nat. Mus. 103666, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 8377–92 feet, ×1. (p. 272)

16, 17—*Ataxioceras* sp. *16*, Specimen, U. S. Nat. Mus. 103667; *17*, specimen, U. S. Nat. Mus. 103668. Both specimens from Smackover formation, Phillips-Kendricks no. 1 well at depths of 8279–94 feet, ×1. (p. 273)

18, 22—*Idoceras* cf. *I. complanatum* Burckhardt. Specimens, U. S. Nat. Mus. 103663, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 8048–63 feet, ×1. (p. 271)

19—*Metahaploceras* cf. *M. nereus* (Fontannes). Specimen, U. S. Nat. Mus. 103661, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 7654–64 feet, ×1. (p. 271)

20—*Glochiceras fialar* (Oppel) of Burckhardt. Specimen, U. S. Nat. Mus. 103662, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 8048–63 feet, ×1. (p. 271)

21—*Idoceras* cf. *I. lorioli* Burckhardt. Specimen, U. S. Nat. Mus. 103665, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 8048–63 feet, ×1. (p. 272)

23—*Idoceras* cf. *I. durangense* Burckhardt. Specimen, U. S. Nat. Mus. 103664, Cotton Valley formation, Phillips-Kendricks no. 1 well at depths of 8048–63 feet, ×1. (p. 271)

Figures *1–6* are from rubber casts of external molds.

prominent, widely spaced, prorsiradiate primary ribs; of bi-, tri-, and multiplicate branching; of equidistant secondary ribs that are strongest on the venter, and of pronounced constrictions is characteristic of the genus *Ataxioceras* as described by Fontannes (1879, pp. 65–70, pl. 10) and Arkell (1935, pp. 253–255, pl. 11). The association of the specimens with *Idoceras* and their position from 215 to 315 feet below beds containing *Glochiceras fialar* (Oppel) and *Idoceras* of the group of *I. durangense* Burckhardt leave no doubt as to their lower Kimmeridgian age.

Figured specimens.—U. S. Nat. Mus. 103667, 103668.

Occurrence.—Cotton Valley formation, Phillips Petroleum Company's Kendrick no. 1 well at depths of 8279–94 feet and 8377–92 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

Genus DICHOTOMOSPHINCTES Buckman, 1926

DICHOTOMOSPHINCTES? sp.

Plate 41, figures 7, 8

Two fragments of ammonites bear nearly straight, narrow, rodlike, slightly prorsiradiate, primary ribs that bifurcate on the ventrolateral margin in such a manner that the posterior branch is a continuation of the primary rib, and the anterior branch inclines sharply forward. Interspaces are about three times as wide as the ribs. The character of the ribbing is similar to that of *Dichotomosphinctes* cf. *D. plicatilis* (d'Orbigny) of Burckhardt (1912, p. 22, pl. 4, figs. 2–4), from the upper Argovian of eastern Durango, Mexico.

Figured specimens.—U. S. Nat. Mus. 103670.

Occurrence.—Smackover formation, Phillips Petroleum Company's Kendricks no. 1 1 well at depths of 8741–56 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

Genus DISCOSPHINCTES Dacqué, 1914

DISCOSPHINCTES cf. D. VIRGULATUS (Quenstedt) of Burckhardt

Plate 41, figures 9–11

Four crushed fragmentary ammonites are ornamented with fine, densely spaced, nearly straight, gently prorsiradiate ribs, of which many remain simple but the majority bifurcate at or slightly above the middle of the flanks. One secondary rib branches again on the upper third of the flank. The ribs arch forward on the venter and show no diminution in strength along the midline. Interspaces are somewhat narrower than the ribs. Several weak constrictions are present.

The ribbing of the species is apparently identical with that of *D. virgulatus* (Quenstedt) of Burckhardt (1912, p. 35, pl. 7, figs. 4–14), from the upper Argovian of eastern Durango, Mexico. One of the fragments herein figured on plate 41, figure 11, has more robust ribbing than the others and is comparable to a form figured by Burckhardt (1912, pl. 7, figs. 5, 6). Reference of the fragments to *Discosphinctes* rather than *Lithacoceras* is indicated by their association with an ammonite that is probably a *Dichotomosphinctes* and by their occurrence about 350 feet below beds containing *Ataxioceras* and *Idoceras*.

Figured specimens.—U. S. Nat. Mus. 103671a–c.

Occurrence.—Smackover formation, Phillips Petroleum Company's Kendricks no. 1 well at depth of 8741–56 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

DISCOSPHINCTES? cf. D. LUCINGENSIS (Choffat) of Burckhardt

Plate 41, figures 12–14

Three partly crushed fragments of ammonites bear fairly strong, rodlike, gently prorsiradiate ribs, of which about one-half remain simple and the remainder bifurcate at or a little above the middle of the flanks. The ribs arch forward on the venter and are not reduced in strength along the midline. Interspaces are about 1½ times as wide as the ribs. One pronounced constriction is present.

The ribbing of this species is much coarser than that of the form compared with *D. virgulatus* (Quenstedt) and is nearly as coarse as that of *D. lucingensis* (Choffat) of Burckhardt (1912, p. 28, pl. 5, figs. 5, 8, 9), from the upper Argovian of eastern Durango Mexico.

Figured specimens.—U. S. Nat. Mus. 103672a–c.

Occurrence.—Smackover formation, Phillips Petroleum Company's Kendricks no. 1 well at depths of 8741–56 feet, sec. 22, T. 19 N., R. 11 W., Bossier Parish, Louisiana.

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JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, PP. 277–281, PLS. 42, 43, 4 TEXT FIGS., MAY 1945

AMMONITES FROM THE DIERKS LIMESTONE OF SOUTHERN ARKANSAS

RALPH W. IMLAY
Geological Survey, Washington, D. C.

ABSTRACT—A new species of the ammonite *Pseudosaynella* from the Dierks limestone of southern Arkansas is described. Faunal and stratigraphic evidence for the upper Aptian age of the Dierks limestone is presented.

DURING October 1943, Paul Applin and I, while examining Comanche outcrops in southern Arkansas, were so fortunate as to obtain three well-preserved ammonites of the genus *Pseudosaynella* from the Dierks limestone, whereas previous collections had furnished only two fragmentary ammonites referred to *Pseudosaynella walcotti* (Hill) (Hill, 1888, p. 128, 1893, p. 37; Scott, 1940, p. 995) and to *Uhligella?* sp. ind. (Scott, 1940, pp. 998, 999). In contrast to the scarcity of ammonites, the limestone had furnished an abundance of pelecypods and of wormlike tubes mainly identical with species in the overlying DeQueen limestone, or in the Glen Rose limestone of Texas (Stanton in Miser and Purdue, 1929, pp. 85, 86). Undoubtedly the presence of the same species in these three formations influenced Stanton's (1928, p. 403) opinion that the Dierks limestone represented some part of the Glen Rose limestone, and that rocks of Travis Peak age probably did not occur as far north as Arkansas and Oklahoma. On the contrary, the presence of *Pseudosaynella* influenced Scott (1926, p. 39; 1940, pp. 976, 994) to regard the Dierks limestone as of upper Aptian age and, therefore, equivalent to some part of the Travis Peak formation.

My studies of the ammonites of the Dierks limestone and of closely related subsurface beds, and of the stratigraphic relationships of these or equivalent beds from Arkansas to south Texas, have demonstrated that the limestone is of upper Aptian age and may be correlated with the Cow Creek limestone member of the Travis Peak formation of the Central Mineral region of Texas.

Faunal evidence of an upper Aptian age for the Dierks limestone consists (1) of the presence of *Pseudosaynella* in the Dierks limestone, (2) of the association of *Pseudosaynella* with *Dufrenoya* and *Parahoplites* in the upper part of the Pine Island shale directly below the James limestone (equals Dierks limestone) in the subsurface of northern Louisiana, and (3) the association of *Pseudosaynella* with *Dufrenoya* in the Cow Creek limestone in the Central Mineral region.

Pseudosaynella in Europe is represented by a few described species occurring only in beds of upper Aptian age (Sarasin, 1893, pp. 156–164; Kilian, 1907, p. 260; 1910, p. 17; Kilian and Reboul, 1915, pp. 30, 33; Spath, 1923, p. 66). It may possibly have a longer range but has never been recorded in the many papers dealing with lower and middle Albian faunas, although the similar genera *Sonneratia* and *Cleoniceras* have been recorded many times.

In the subsurface of southern Arkansas and Louisiana the equivalent of the Dierks limestone, called the James limestone, is commonly coquinoid but has not furnished determinable fossils. However, cores from the upper part of the underlying Pine Island shale have furnished specimens of *Dufrenoya*, *Hypacanthoplites*, *Parahoplites?*, and *Pseudosaynella* (Hazzard, 1939, pp. 159–162). The occurrence of either *Dufrenoya* or *Pseudosaynella* justifies assigning the shale to the upper Aptian. As some specimens of *Dufrenoya* occur in the upper few feet of the shale, the age of the overlying James limestone must be either late Aptian or basal Albian. The occurrence of these fossils is tabulated below.

The Travis Peak formation of the Central Mineral region of Texas has been correlated with the upper Aptian on the basis of the

occurrence of *Dufrenoya* in the Cow Creek limestone, which forms the middle member of the formation (Burckhardt, 1925, p. 17; Scott, 1926, p. 119; 1940, pp. 1022–24). Correlation of the Cow Creek limestone with the Dierks limestone of Arkansas is suggested by the reported occurrence of *Pseudosaynella walcotti* (Hill) (Cuyler in Adkins, 1933, p. 315; Damon and McNutt, 1940, p. 9).

DISTRIBUTION OF AMMONITES IN THE PINE ISLAND SHALE

Ammonites from upper part of Pine Island shale of northern Louisiana	Shreveport Oil Corp., Muslow no. D-1, sec. 5, T. 20 N., R. 15 W., Caddo Parish, La. Top of Pine Island shale 4211.	Gay et al., Long Bell Lbr. Co., No. A-1, sec. 10, T. 8 N., R. 13 W., Sabine Parish, La. Top of Pine Island shale 6620?	United Gas Co., Meadows no. 1, sec. 13, T. 21 N., R. 5 W., Claiborne Parish, La. Top of Pine Island shale 4820?	Standard Oil Co. of La., Fudicker no. 1, sec. 2, T. 17 N., R. 19 W., Webster Parish, La. Top of Pine Island shale 6185.	Prarie River Synd. Hutchinson no. 1, sec. 15, T. 15 N., R. 12 W., Caddo Parish, La. Top of Pine Island shale 5150.	Haynes Prod. Co., Murff no., 1, sec. 36, T. 17 N., R. 12 W., Bossier Parish, La. Top of Pine Island shale 4955
Dufrenoya aff. *D. dufrenoyi* (d'Orbigny) of Burckhardt	—	6626–36	4825–34	6202–06	—	—
Dufrenoya texana Burckhardt	—	—	—	—	—	5082–5140
Dufrenoya cf. *D. texana* Burckhardt	4267	—	—	—	—	—
Dufrenoya sp.	4268	—	—	—	—	—
Hypacanthoplites sp.	4260–65	—	—	—	5366–86	—
Rhytidhoplites robertsi Scott?	—	—	—	—	5366–86	—
Parahoplites? sp.	4296	—	—	—	5350–84	5128–47
Pseudosaynella sp.	4295	—	—	—	—	—
Pseudosaynella? sp.	4286	—	—	—	—	—

Stratigraphic evidence of an upper Aptian age for the Dierks limestone is based on studies of the subsurface Lower Cretaceous formations of southern Arkansas, northern Louisiana, and eastern and southern Texas. This evidence, which will be presented in detail in other papers, shows that the Pine Island shale can be traced from Arkansas to south Texas and thence updip into the basal member of the Travis Peak formation; that the Pine Island shale of south Texas is overlain by a limestone that can be traced updip into the Cow Creek limestone member of the Travis Peak formation; and that the Cow Creek limestone occupies the same stratigraphic position as the James and Dierks limestone.

SYSTEMATIC DESCRIPTIONS

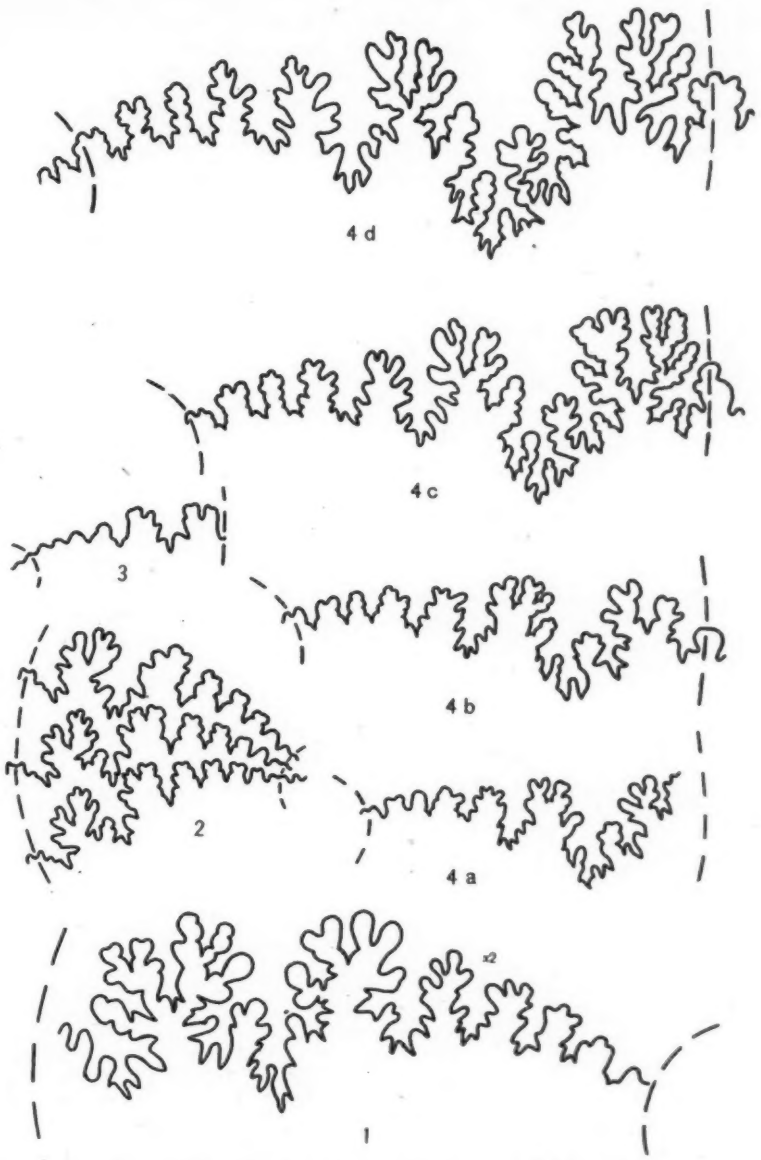
Genus PSEUDOSAYNELLA Spath, 1923

PSEUDOSAYNELLA FIMBRIATA Imlay, n. sp.

Plate 42, figure 1; plate 43, figures 1–5; text figures 2, 3, and 4a–d

This species is represented by three internal molds that do not show the body chamber. Form large, discoidal, much compressed; whorls wedge-shaped in section, much higher than wide, thickest at about one-third the distance from the umbilicus to the venter, embracing about four-fifths; flanks flattened in lower third, sloping gently above toward a sharpened venter. Umbilicus narrow; wall moderately high, vertical, rounding abruptly into flanks.

The smaller molds are ornamented with many low, broad, flexuous, regularly spaced ribs, of which most are slightly broader than the interspaces. The ribs begin at the umbilical wall, are faint on the lower part of the flank, become stronger ventrally, bifurcate



FIGS. *1*—*Pseudosaynella walcotti* (Hill). Suture line of holotype at whorl height of 44 mm., ×2.
2–4—*Pseudosaynella fimbriata* Imlay, n. sp., ×1. *2*, Suture of paratype (U. S. Nat. Mus. 103715b) at whorl height of 36 mm. *3*, Suture of paratype (U. S. Nat. Mus. 103715a) at whorl height of 20 mm. *4*, Sutures of holotype (U. S. Nat. Mus. 103714) at whorl heights of *a*, 58 mm.; *b*, 67 mm.; *c*, 87 mm.; *d*, 104 mm.

at, or slightly above, the middle of the flank, and number 55 to 60 per whorl on the upper part of the flank. About six rather weak constrictions are present.

The largest mold appears to be nearly smooth, but when viewed under oblique lighting it exhibits very faint, broad, falciform ribs and five or six faint constrictions.

The suture lines are well exposed but owing to weathering show fewer convolutions than would be expected if the shell were present. The siphonal lobe is broad and short; the first lateral lobe is long, deep, and very asymmetrical; the second lateral lobe is considerably shorter than the first and less asymmetrical. There are four auxiliary lobes on the flank and three on the umbilical wall. The siphonal saddle is broad, divided rather deeply by a secondary lobe into two branches, of which the inner branch is slightly the larger; first lateral saddle is much narrower than the siphonal saddle but is nearly as high and is almost symmetrically divided; second lateral saddle is lower and more narrow than the first; auxiliary saddles becomes progressively lower and simpler dorsally, but the saddle on the umbilical shoulder is much broader than the adjacent saddles.

Dimensions in millimeters of the three specimens of *Pseudosaynella fimbriata* are given below. Numbers in parenthesis are ratios of the diameter to the other dimension. The dimensions of *P. walcotti* (Hill) are included for comparative purposes.

Specimen	Greatest diameter	Whorl height	Whorl thickness	Umbilical width
P. fimbriata, pl. 42, fig. 1	193	104 (.54)	43 (.22)	28 (.14)
P. fimbriata, pl. 43, figs. 4, 5	82	46 (.56)	16.5 (.20)	11 (.13)
P. fimbriata, pl. 43, figs. 1, 2	78	43 (.55)	18 (.23)	9 (.12)
P. walcotti, holotype	92	47 (.51)	26 (.28)	15 (.16)

Pseudosaynella walcotti (Hill) (1888, p. 128, pl. 1, figs. 1, 1a, 1b; Scott, 1940, p. 995, pl. 56, figs. 1, 2) differs from *P. fimbriata* by having a thicker whorl section, a wider umbilicus, sparser, thinner ribbing, and probably a shorter siphonal lobe (text fig. 1). The described European species of *Pseudosaynella* (Sarasin, 1893, p. 156–164, pls. 4–6) are known only from small and probably immature specimens that are difficult to compare with the large specimens of *P. fimbriata*. *Pseudosaynella bicurvata* (Michelin) (1838, p. 101, pl. 12, fig. 7; Sarasin, 1893, p. 161, figs. 8, 9, pl. 4, 5, figs. 1a, 1b, 2a, 2b, 3a, 3b) is probably the most similar but has fainter ribbing and a thicker whorl section.

Types.—Holotype U. S. Nat. Mus. 103714; paratypes U. S. Nat. Mus. 103715a, b.

Occurrence.—Dierks limestone. Holotype collected about 3 miles west of Nathan in southwest corner of sec. 26, T. 7 S., R. 27 W., Howard County, Arkansas. Paratypes collected about 2 miles northeast of Murfreesboro in northeast corner of sec. 9, T. 8 S., R. 25 W., Pike County, Arkansas.

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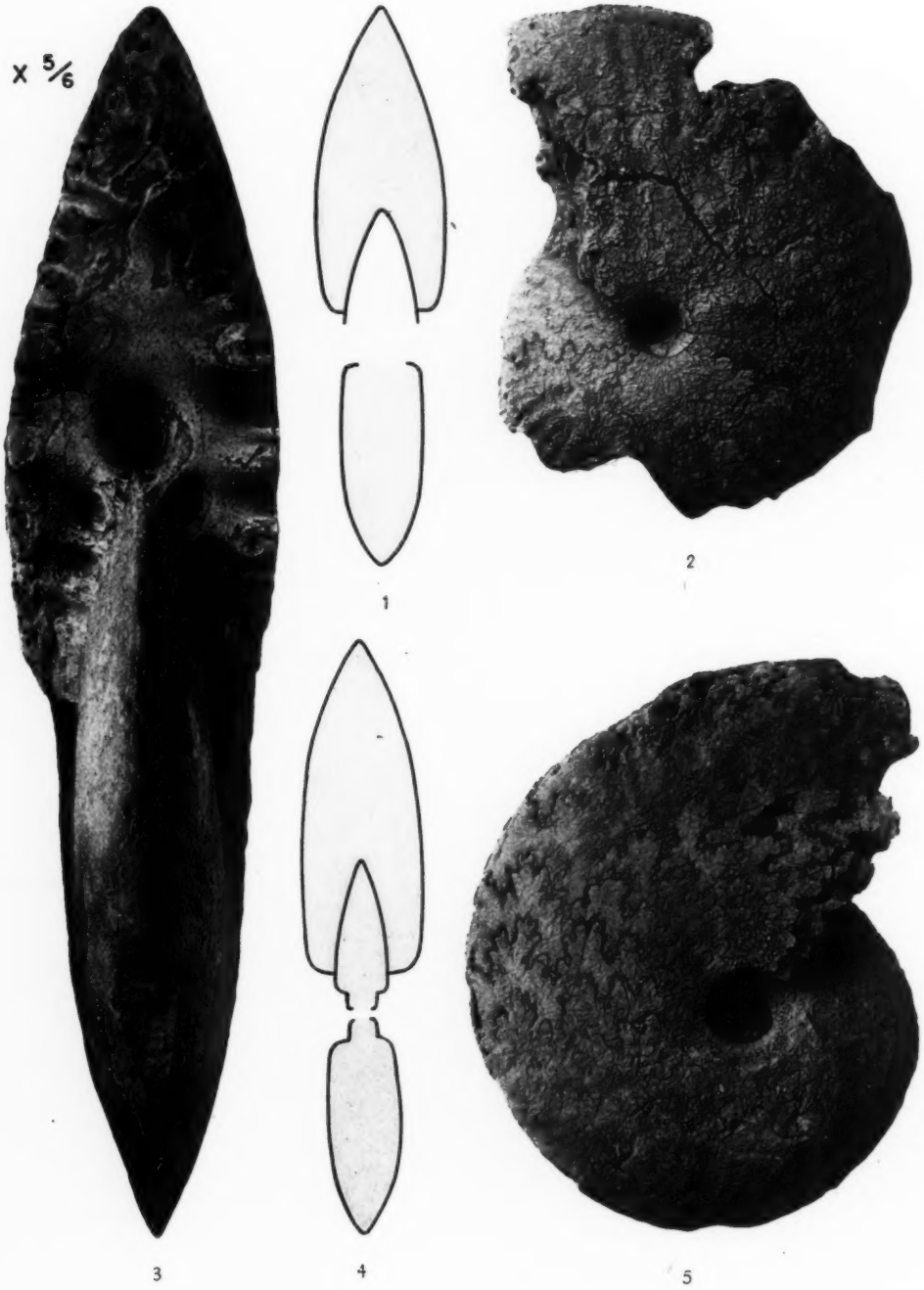
EXPLANATION OF PLATE 42

FIG. *1*—*Pseudosaynella fimbriata* Imlay, n. sp. Holotype, ×$\frac{3}{4}$. From 3 miles west of Nathan in southwest corner of sec. 26, T. 7 S., R. 27 W., Howard County, Arkansas. U. S. Nat. Mus. 103714. (p. 278)

1

Imlay, Ammonites from Dierks Limestone



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EXPLANATION OF PLATE 43

FIGS. *1–5—Pseudosaynella fimbriata* Imlay, n. sp. *1, 2,* Paratype, U. S. Nat. Mus. 103715a, ×1. *3,* Apertural view of holotype U. S. Nat. Mus. 103714, ×$\frac{3}{4}$. *4, 5,* Paratype, U. S. Nat. Mus. 10715b, ×1. Paratypes from 2 miles northeast of Murfreesboro in northeast corner of sec. 9, T. 8 S., R. 25 W., Pike County, Arkansas. (p. 278)

JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, PP. 282–294, PLS. 44, 45, 2 TEXT FIGS., MAY 1945

PERMIAN NAUTILOIDS FROM THE GLASS MOUNTAINS AND THE SIERRA DIABLO OF WEST TEXAS

A. K. MILLER
State University of Iowa, Iowa City, Iowa

ABSTRACT—Recent collecting in the classical Permian of west Texas has yielded representatives of *Stenopoceras* from the Hueco formation; *Michelinoceras*, *Mooreoceras*, *Pseudorthoceras*, *Metacoceras*, and *Cooperoceras?* from the Bone Spring; *Mooreoceras?*, *Domatoceras?*, *Metacoceras*, and *Stenopoceras* from the Leonard; and *Mooreoceras*, *Metacoceras*, and *Cooperoceras* from the Word. Most of these are typical Permian forms. However, one new genus, *Cooperoceras*, and several new species are represented by the available material.

AS HAS recently been emphasized (Miller and Unklesbay, 1942), the nautiloids of Permian times are not nearly as well known as are the ammonoids. However, it seems almost certain that their relative scarcity is somewhat more apparent than real. That is, because of their superior stratigraphic value, ammonoids have been sought more diligently than nautiloids, and their discovery has been recorded more often. For example, most of the specimens illustrated in this report came from the Glass Mountains, from which many Permian ammonoids have been described but from which not a single Permian nautiloid has even been listed.

These Glass Mountain nautiloids, on which the major portion of this report is based, are exquisite silicified specimens which elucidate clearly many features of the shell. They were loaned to me by G. A. Cooper of the U. S. National Museum, who secured them by collecting large blocks of fossiliferous limestone and dissolving the calcareous matrix in hydrochloric acid. By keeping the acid dilute, to avoid a violent reaction, and carrying on the dissolving process over a long period of time, he was able to obtain specimens that retain delicate spinose processes (pl. 44, figs. 3, 4). In a similar manner Stanislaus Kříž of Princeton University secured a collection of comparable material from the Sierra Diablo, which J. B. Knight called to my attention and arranged to have loaned to me. Furthermore, Harold Vokes of the American Museum of Natural History sent me some specimens that he collected in the Glass Mountains. Acknowledgement is also due to Lee Allen and Joan M. Cox, who retouched the photographs that accompany this report, and to the Graduate College of the State University of Iowa, which made the completion of this study financially possible.

In addition to the specimens discussed in detail on the following pages, the available collections contain numerous fragments that are too incomplete to merit illustration or detailed description. Some of those known from the Bone Spring limestone of the Sierra Diablo represent large specimens several inches in diameter, but unfortunately even their generic affinities can not be determined. As might be expected, these large shells were very thick, and most of them contain numerous depressions that are lenticular in cross section and are only a few millimeters long—presumably these were made by boring sponges.

The generic position of a few of the undescribed fragments can be suggested, and altogether the following nautiloids are now known from the Bone Spring formation:

Michelinoceras spp.
Mooreoceras sp.
Pseudorthoceras sp.
Metacoceras mammiferum, n. sp.
Metacoceras megaporum, n. sp.
Metacoceras spp.
Cooperoceras? sp.

All of these forms occur at the same horizon and locality, that is, all of them are represented on the so-called "Molluscan Ledge" in massively bedded limestone about 100 feet above the base of the Bone Spring formation in the northwestern wall of the mouth of Apache Canyon about 0.2 mile north of the Van Horn quadrangle, in the

Sierra Diablo of Hudspeth County, Texas. This locality is the one that yielded the holotype of the ammonoid *Propinacoceras knighti* Miller and Furnish. From the southeastern wall of Apache Canyon, Kříž secured a single crushed representative of *Metacoceras* from the black limestone of the Bone Spring formation, about 100 feet above the highest ledges of the massively bedded highly fossiliferous limestone. It should also be mentioned here that Kříž found a fragment of an unnamed species of *Stenopoceras* in the basal limestones and shales at the base of a downfaulted block of the Lower Permian Hueco formation on the southern side of Apache Springs Canyon in the Sierra Diablo.

The Leonard formation of the Glass Mountains is the approximate stratigraphic equivalent of the Bone Springs formation. From the upper part of the Leonard on the slopes along the southern side of the road 0.2 to 0.5 mile east of Split Tank and 1.5 miles northwest of the bowed fork near the old Word Ranch house, some 19 miles north-northeast of Marathon, Texas, G. A. Cooper collected a variety of excellent silicified nautiloids, all but one of which are congeneric:

Metacoceras cooperi, n. sp.
Metacoceras gregarium, n. sp.
Metacoceras magnicostatum, n. sp.
Metacoceras mutatum, n. sp.
Metacoceras sp.
Stenopoceras inexpectans, n. sp.

Also, near the top of the slope on the northwest side of the road about ½ mile southwest of the old Word Ranch house, Cooper obtained *Mooreoceras?* sp. and *Domatoceras?* sp. He believes that the beds from which these two forms came are the lower limestone member of the Word formation, but he states that in the field he "felt that there was quite an overlap between the base of the Word and the top of the Leonard." However, his collections from this horizon and locality contain numerous representatives of *Perrinites hilli* (Smith), an ammonoid that for some years has been regarded as characteristic of the Leonard and has never been found in the Word. It therefore seems to me that the beds which yielded the fossils under consideration are most probably in the upper part of the Leonard formation.

The nautiloids of the Leonard are more like those of the Bone Spring than the above lists would seem to imply, though the latter formation seems to carry many more orthocones than does the former. One genus of nautilicones, *Metacoceras*, is abundant in both faunas, but no particular significance should be attached to this fact, for locally that genus is abundant throughout the late Paleozoic.

Although ammonoids are abundant in the Word formation, which overlies the Leonard nautiloids seem to be rather rare in it. However, in the third limestone member of the Word on the northern slope of the hill on the southern side of Hess Canyon about 4 miles N. 35° E. of the Hess Ranch house some 14 miles north-northeast of Marathon, Cooper secured a few silicified specimens of *Mooreoceras* sp., *Metacoceras gregarium*, n. sp.?, and *Cooperoceras texanum*, n. sp. Also, Harold E. Vokes obtained a well preserved representative of *Mooreoceras* in the Word formation on the southern side of a spur on the eastern side of Gilliland Canyon extending northwest to benchmark 4973 in the Glass Mountains.

No Permian nautiloid faunas are known that are strikingly similar to those described in this report. At the same time, it can be said that almost all such faunas contain the same generic elements as do these west Texas assemblages under consideration. It seems quite likely that equivalent beds in other areas, both in this country and abroad, contain similar faunas but that they have never been collected, illustrated and described.

SYSTEMATIC PALEONTOLOGY

MICHELINOCERAS, MOOREOCERAS, and PSEUDORTHOCERAS spp.

Plate 44, figures 7–10

The collections on which this report is based contain more than a hundred fragmentary smooth round orthocones from the Permian of west Texas. Most of these are small, but some attain a diameter of as much as 20 mm. or more. They show an amazing amount of variation in the rate of adoral expansion of the conch, the length of the

camerae, the concavity of the septa, and the nature and position of the siphuncle.

At present it would be conventional to place those with subcentral cyrtochoanitic siphuncles in *Mooreoceras* and those with central orthochoanitic siphuncles in *Michelinoceras*. However, most of the specimens under consideration are silicified replacements, and it is not possible to ascertain whether they have orthochoanitic or cyrtochoanitic siphuncles, though both types are definitely present. Furthermore, several of the small specimens represent the extreme adapical part of the conch, and some of these are straight, as presumably is the case in typical *Michelinoceras* and *Mooreoceras*, whereas others are slightly curved, indicating that they belong in *Pseudorthoceras*. Furthermore, in one of the moderate-sized specimens with a cyrtochoanitic siphuncle, I found traces of the cameral deposits that are so characteristic of *Pseudorthoceras*. In my opinion, all three of these genera are represented in the collections under consideration, but I am unfortunately not able to determine the generic affinities of many individual specimens with certainty.

Occurrence.—The great majority of these specimens (including pl. 44, fig. 7) came from about 100 feet above the base of the Bone Spring limestone near the mouth of Apache Canyon about 0.2 mile north of the Van Horn quadrangle on the second promontory north of the lower bench on the outside rim of the northern part of Apache Canyon in the Sierra Diablo of Hudspeth County, Texas—all three of the genera mentioned are represented at this horizon and locality. The specimen represented by figure 9 on plate 44, of which the generic affinities are very uncertain, came from the upper Leonard (or possibly the lower Word) limestone near the top of the slope on the northwest side of the road about 0.5 mile southwest of the old Word Ranch house, some 17 miles north-northwest of Marathon, Brewster County, Texas. The specimen represented by figure 8 on plate 44 (and six very similar ones) came from the third limestone of the Word formation on the northern slope of the hill on the southern side of Hess Canyon about 4 miles N. 35 °E. of the Hess Ranch house, some 14 miles north-northeast of Marathon. Figure 10 on plate 44 represents a specimen from the Word formation at elevation 5250 on the southern side of a spur on the eastern side of Gilliland Canyon extending northwest to benchmark 4973 in the Glass Mountains of Brewster County, Texas.

Repositories.—Princeton University (specimens from the Sierra Diablo, including pl. 44, fig. 7); U. S. National Museum (specimens from the Marathon region, including pl. 44, figs. 8, 9, but not 10), 111609, 111609a–f, 111610; and American Museum of Natural History (pl. 1, fig. 10).

DOMATOCERAS? sp
Plate 44, figures 1, 2

The collections under consideration contain a moderately small silicified nautilicone of uncertain generic affinities. The size of this specimen and the fact that the shape of its conch changes fairly rapidly throughout its entire length indicate that it is immature. It seems to resemble early ontogenetic stages of *Domatoceras*, and accordingly I am referring it with question to that genus.

This specimen, which consists of some one and one-half volutions, is about 25 mm. in diameter, and all but the extreme adoral portion of it is septate. The living chamber, when complete, appears to have been about two-fifths of a volution in length. The conch is expanded orad rapidly, and at the adoral end of the specimen is about 21.5 mm. wide and 13 mm. high. Corresponding measurements at the adapical end of the outer volution are about 10 mm. and 5 mm., respectively. At the latter place, the conch appears to be subelliptical in cross section, being more broadly rounded dorsally than ventrally. However, throughout the length of the outer volution of this specimen, the conch becomes progressively more flattened ventrally and laterally and the umbilical shoulders become higher and higher. The lateral zones converge ventrally, and at the adoral end of this specimen the conch is unequally hexagonal in cross section, with the dorsal side slightly concave and all of the other sides slightly convex.

The umbilicus of this specimen attains a diameter of about 10 mm. The umbilical shoulders are abrupt, and the umbilical walls are steep. An umbilical perforation, if any existed, was very small.

The camerae are moderate in length. In the adapical part of the specimen the sutures are essentially straight and directly transverse, but in the adoral portion of it they form slight lateral and ventral lobes. No trace of the siphuncle is visible.

Remarks.—Superficially, at least, this specimen resembles the adapical portion of large representatives of *Domatoceras*. If, however, as is now believed, it is immature, its generic affinities can not be determined with certainty. Representatives of *Domatoceras* are now known to be widespread in the northern hemisphere and to range in age from lower Pennsylvanian to Upper Permian. They are fairly abundant in the Pennsylvanian of both the United States and Soviet Russia and occur also in the Permian of these two countries as well as India and Timor.

Occurrence.—Near the top of the slope on the northwest side of the road about 0.5 mile southwest of the old Word Ranch house, some 17 miles north-northwest of Marathon, Brewster County, Texas. G. A. Cooper, who collected the specimen, is inclined to believe that the limestone from which it came is the first limestone of the Word formation, but he states that in the field he "felt that there was quite an overlap between the base of the Word and the top of the Leonard." Inasmuch as he found typical representatives of *Perrinites hilli* (Smith) in association with this specimen, I am of the opinion that the beds which yielded it are part of the Leonard formation.

Repository.—U. S. National Museum, 111611.

Genus METACOCERAS Hyatt, 1883

Nautilicones, in which the mature whorls are only slightly involute and are more or less square in cross section and the test bears lateral ribs and ventrolateral nodes, are abundant and widespread in the Pennsylvanian and Permian strata of at least North America and Eurasia. Even a moderate-sized collection of them from one or more horizons exhibits a great deal of variation in the details of the ribs, nodes, etc. It is therefore difficult indeed to determine the limits of species within this group and to tell how much taxonomic value to accord the variations.

The collections under consideration are no exception to this generalization. Furthermore, most of the specimens show a considerable amount of ontogenetic variation. For example, the individual represented by figure 11 on plate 45 has a very distinct dorsolateral carina on the adapical portion of the outer volution and the adjacent part of the next volution, but that carina gradually disappears both adorally and adapically. Another specimen from the same horizon and locality bears prominent lateral ribs on all but the extreme adoral part of its conch, and the change from ribbed to smooth lateral zones is abrupt.

After careful consideration, it seems to me that the well-preserved specimens in the available collections from one locality (near Split Tank) in the Glass Mountains contain four fairly distinct representatives of *Metacoceras*. It may well be that all these forms should be regarded as belonging in a single species, of which we should recognize four varieties, for more or less intermediate forms are almost certain to be found. However, varietal names are so cumbersome that as a matter of expediency I propose to regard each of these several variants in the Leonard as a distinct species. If in the future it is found that the other procedure should have been followed, I suggest that the form I am terming *Metacoceras gregarium* be regarded as the standard and the others as varieties of it, for that form is most abundant and in addition it is more or less intermediate between the extremes.

Both of the representatives of *Metacoceras* known from the Word formation of the Glass Mountains are so poorly preserved that their specific affinities can not be determined satisfactorily. Also, many of the specimens available from the Bone Spring limestone of the Sierra Diablo are very fragmentary, but they do not seem to be referable to species that occur in the Leonard.

METACOCERAS COOPERI, n. sp.
Plate 45, figures 11, 12

The holotype of this species is an exceptionally fine specimen that represents about two volutions of the conch. It is almost but not quite complete adapically and adorally. The maximum diameter attained by the preserved part of this specimen measures

about 65 mm., and near its adoral end its conch is about 27 mm. high and about 29 mm. wide. Its umbilicus attains a diameter of about 26 mm., and its umbilical perforation was about 5 mm. long and about 3 mm. wide. The umbilical walls are steep and are almost perpendicular to the flattened lateral zones of the conch.

The adapical half of the first volution of the conch is subcircular in cross section, but the rest of it is almost square, though at full maturity it is slightly concave both dorsally and ventrally. The change in the shape of the cross section is abrupt. On the subcircular adapical part of the conch the growth lines are fairly prominent. Elsewhere they are not conspicuous, but at maturity they are nearly straight on the lateral zones of the conch and form a deep rounded ventral salient. At the adoral end of the first half volution of the conch, a rounded inconspicuous dorsolateral keel is developed. It is never very prominent and on the adoral half volution of the holotype is essentially obsolete. At the same time that the conch became more or less square in cross section and developed a dorsolateral keel, it developed lateral ribs, which are much more prominent on the ventral half of the lateral zones than on the dorsal half. These ribs gradually diminish dorsally and they do not extend quite to the dorsolateral keel. Ventrolaterally they end abuptly and form very narrowly rounded nodes. On the extreme adoral part of the holotype, these lateral ribs seem to become obsolete.

No trace of the siphuncle is visible on the holotype. However, the collections under consideration contain three fragmentary specimens (paratypes) that I am referring to this species, and one of them shows that the siphuncle is small and is located somewhat nearer the venter than the dorsum.

Remarks.—This species resembles *Metacoceras magnicostatum*, with which it occurs. However, the ribs or nodes on its conch are smaller, the dorsolateral keel is less prominent, and the umbilical perforation is considerably smaller.

Occurrence.—Upper Leonard south of the road 0.2–0.5 mile east of Split Tank, 1½ miles northeast of the bowed fork near the old Word Ranch house, about 19 miles north-northeast of Marathon, Brewster County, Texas.

Types.—U. S. National Museum; 111612 (holotype) and 111613 (three paratypes).

METACOCERAS GREGARIUM Miller, n. sp.
Plate 45, figures 5–8

The collections under consideration contain six specimens on which I am basing this species. The largest of the figured specimens (pl. 45, fig. 8) consists of slightly more than two volutions, and it attains a maximum diameter of about 63 mm. Near the adoral end of this specimen the conch is about 26 mm. high, and near the midlength of the outer volution it is about 17 mm. high and about 20 mm. wide. The conch of one of the unfigured syntypes attains a height of as much as 28 mm.

The umbilicus is large and open, and that of the large figured specimen just discussed measures about 26 mm. in diameter. The umbilical perforation of this specimen is about 5½ mm. long and 3½ mm. wide; that of the syntype represented by figures 5 and 6 on plate 45 is slightly larger and measures about 6 mm. in length and 4 mm. in width. The umbilical walls are steep, being almost perpendicular to the lateral zones of the conch.

The adapical half of the first volution of the conch is rapidly expanded orad and is circular or nearly so in cross section. Then the conch becomes abruptly flattened laterally, dorsally, and ventrally. After it has completed one full volution it becomes slightly concave dorsally as it develops a shallow impressed zone. and in the outer volution of large individuals it becomes slightly concave ventrally. The dorsolateral (umbilical) shoulders are subangular, but in this species they do not develop an appreciable keel.

On the adapical half of the first volution of the conch the growth lines are very prominent, and also there appears to be a ventrolateral ridge. On the remainder of the conch the growth lines are almost straight and directly transverse on the umbilical walls, but they curve somewhat apicad as they approach the umbilical shoulders. On the lateral zones of the conch their shape is influenced somewhat by the ribs, but they are

either straight or slightly sigmoidal. Ventrally they form rather deep rounded sinuses.

As soon as the conch becomes more or less square in cross section it develops transverse lateral ribs. During early maturity these ribs are much less prominent on the dorsal than on the ventral parts of the lateral zones, and they form rather prominent ventrolateral nodes. However, after full maturity is attained the ribs extend clear across the lateral zones with almost equal prominence, though invariably they end ventrolaterally more abruptly than dorsolaterally. The large unfigured specimen mentioned above indicates that in the extreme adoral portion of very large individuals the lateral ribs abruptly disappear and the conch is essentially smooth.

The septa are rather closely spaced and are moderately convex apicad. Where the conch is about 19 mm. high, the siphuncle is a little more than 1 mm. in diameter and is located about 8 mm. from the venter. It appears to be composed of cylindrical segments and presumably, therefore, is orthochoanitic in structure.

Remarks.—This species can be differentiated from the other congeneric forms described in this report by the fact that at full maturity the lateral ribs extend clear across the lateral zones of the conch with almost equal prominence. Also, these ribs are not as high as are those of *Metacoceras magnicostatum*, and the umbilical perforation of this form is larger than that of *M. cooperi* and smaller than that of *M. megaporum*.

Occurrence.—All of the type specimens of this species came from the upper Leonard south of the road 0.2–0.5 mile east of Split Tank, 1.5 miles northeast of the bowed fork near the old Word Ranch house, about 19 miles north-northeast of Marathon, Brewster County, Texas. Also I am referring with question to this species two rather poorly preserved specimens from the third limestone of the Word formation on the north slope of the hill on the south side of Hess Canyon about 4 miles N. 35° E. of the Hess Ranch house, about 14 miles north-northeast of Marathon.

Syntypes.—U. S. National Museum, 111614 (figured specimens) and 111615 (unfigured specimens). The Word specimens referred to this species with question are U. S. National Museum, 111616.

METACOCERAS MAGNICOSTATUM Miller, n. sp.

Plate 45, figures 9, 10

The single specimen on which this species is based is well preserved and fairly complete. The portion of the conch that it represents consisted of about two and one-fourth volutions. It attained a maximum diameter of about 57 mm. and a maximum height and width of conch of about 22 mm. and 25 mm., respectively. The umbilicus is large and open, and that of the holotype measures about 22 mm. in diameter at the adoral end of the specimen. The umbilical perforation, which is subovate in shape, is about 6.5 mm. long and about 4 mm. wide. The umbilical walls are steep and are almost perpendicular to the flattened lateral zones of the conch.

The adapical half of the first volution of the conch is circular, or nearly so, in cross section, but the rest of it is almost square in cross section as it is flattened laterally, is very slightly concave dorsally and ventrally, is subangular dorsolaterally, and is narrowly rounded ventrolaterally. Apparently only the adoral half of the outer volution is concave ventrally, but the dorsal zone becomes concave during the second half of the first volution and remains so throughout ontogenetic development. Along the center of the ventral concave zone there is a faint ridge. The growth lines are rather prominent on the adapical half of the first volution of the conch. Elsewhere they are very faint, but they seem to be almost straight and directly transverse on the umbilical walls and the lateral zones of the conch but to form deep rounded ventral sinuses.

Except on the adapical half of the first volution of the conch, there is a low rounded carina on the dorsolateral (umbilical) shoulder, and the lateral zones of the conch bear prominent short transverse ribs. Dorsally these ribs die out gradually, and they do not extend quite to the carina on the umbilical shoulder. However, ventrolaterally they end abruptly, and they can be said to form prominent rounded ventrolateral nodes.

The septa are moderately convex apicad. A structure that appears to represent the siphuncle is small, circular in cross section, and is located somewhat closer to the venter than the dorsum.

Remarks.—The most distinctive feature of this species is the prominence of the lateral nodes on its conch. It is perhaps closest to *Metacoceras cooperi*, which, in addition to having smaller nodes, has a less prominent carina on its umbilical shoulder and a smaller umbilical perforation.

The collections under consideration contain a fragmentary specimen, from the same horizon and locality as the holotype, that I am referring with question to this species. It seems to have the same large lateral ribs and prominent dorsolateral keel, but it is too incomplete to serve satisfactorily as a type specimen.

Occurrence.—Upper Leonard south of the road 0.2–0.5 mile east of Split Tank, 1.5 miles northeast of the bowed fork near the old Word Ranch house, about 19 miles north-northeast of Marathon, Brewster County, Texas.

Holotype.—U. S. National Museum, 111617. The specimen referred with question to this species is 111618.

METACOCERAS MAMMIFERUM Miller, n. sp.
Plate 45, figure 2

One of the several specimens on which this species is based elucidates the more significant characters of the species very well, and it is chosen as the holotype (pl. 45, fig. 2). The preserved part of this specimen is estimated to have attained a diameter of about 35 mm. Near the midlength of the remaining portion of the outer volution of this specimen the conch is about 14 mm. high, and its corresponding width is estimated to have been about 18 mm. Two of the fragmentary paratypes represent considerably larger individuals, which appear to have attained dimensions something like 50 per cent larger than those of the holotype.

The umbilicus is large and open, and the umbilical walls are moderately steep. Where the diameter of the conch measures about 26 mm., that of the umbilicus measures about 11 mm. The umbilical perforation is subovate, about 6 mm. long, and about 3.5 mm. wide. The umbilical shoulder is fairly distinct, but it is not keeled during any stage of ontogenetic development.

The adapical half of the first volution of the conch is subcircular in cross section, but at the adoral end of that half volution the conch is abruptly flattened dorsally, ventrally, and laterally. Eventually the dorsal side of the conch becomes concave as it is impressed by the ventral side of the preceding volution, but the ventral side remains slightly convex throughout ontogenetic development.

On the mature portion of the conch the growth lines, which are very fine, are almost straight and directly transverse on the umbilical walls, though they curve rather strongly apicad in the immediate vicinity of the umbilical shoulders. On the lateral zones of the conch the growth lines are slightly sigmoidal, and on the ventral zone they form a deep rather narrowly rounded sinus. Except on its adapical half volution, the conch bears prominent ventrolateral nodes. When these are first developed they have the appearance of short lateral ribs that are particularly prominent ventrolaterally. However, they soon evolved into prominent rounded ventrolateral spinose processes that

EXPLANATION OF PLATE 44

FIGS. *1, 2—Domatoceras?* sp. A specimen from the upper Leonard formation southwest of the old Word Ranch house in the Glass Mountain region of Brewster County, Texas, ×2. (p. 284)

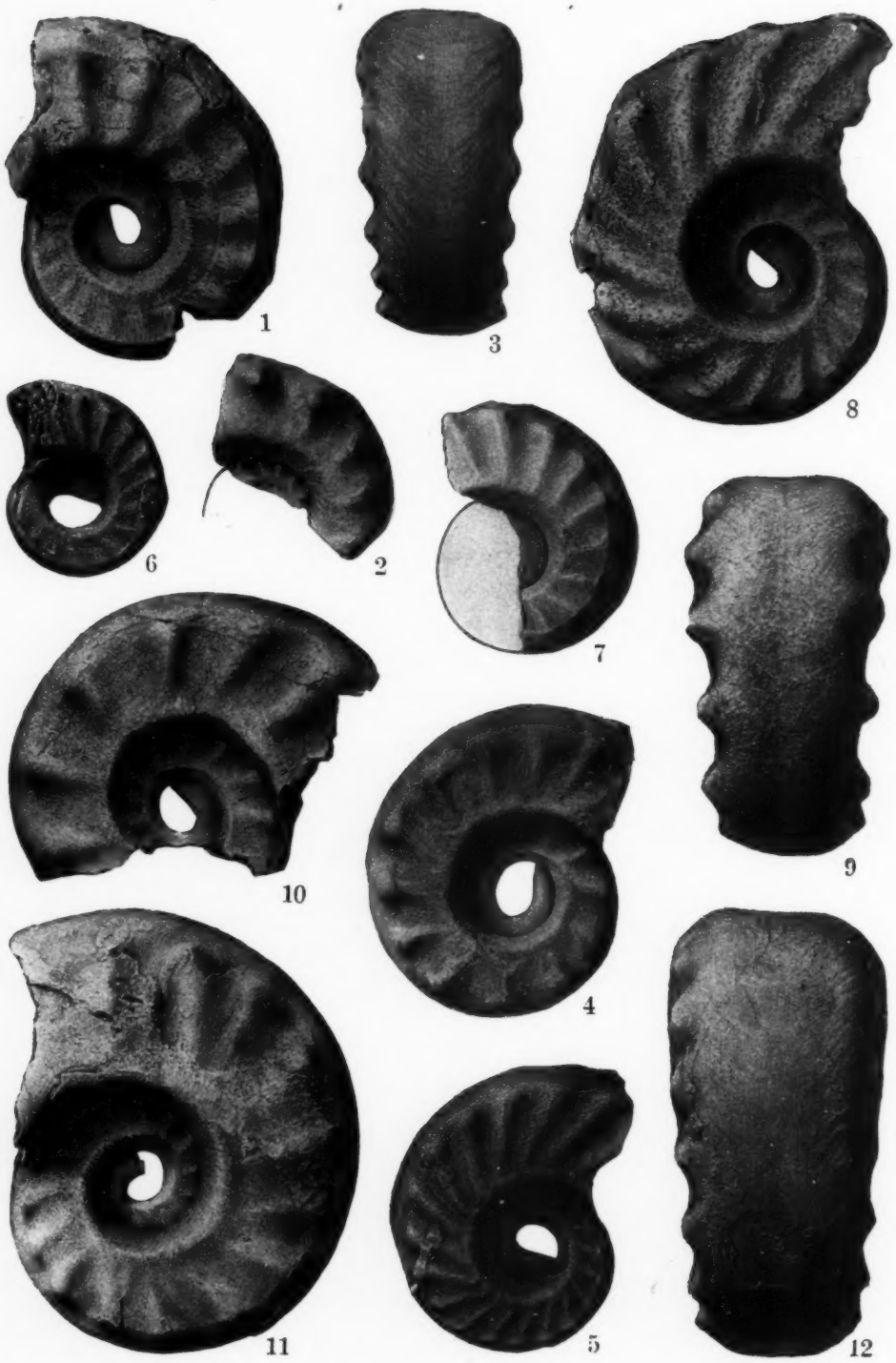
3, 4—Cooperoceras texanum Miller, n. sp. The holotype, from the Word formation in Hess Canyon northeast of the Hess Ranch house in the Glass Mountain region of Brewster County, Texas, ×2. (p. 292)

5, 6—Stenopoceras inexpectans Miller, n. sp. The holotype, from the upper Leonard formation east of Split Tank in the Glass Mountain region of Brewster County, Texas, ×2. (p. 292)

7—Michelinoceras sp. A specimen from the Bone Spring limestone near the mouth of Apache Canyon in the Sierra Diablo of Hudspeth County, Texas, ×1. (p. 283)

8–10—Mooreoceras sp. *8*, ×2, From the same horizon and locality as *3, 4; 9*, ×1, from the same as *1, 2; 10*, ×6, from the Word formation in Gilliland Canyon of the Glass Mountain region of Brewster County, Texas. (p. 283)

Miller, Permian Nautiloids



Miller, Permian Nautiloids

have rather inconspicuous prolongations on the lateral zones of the conch, and they retained this form throughout the life of the individual. There are about 15 of these spines to the volution.

Remarks.—The ventrolateral spines of this species, which are its most distinctive characteristic, are similar to those on the specimen from the Wewoka formation (mid-Pennsylvanian) of Oklahoma that Girty described as *Metacoceras cornutum* var. *sinuosum*. That form is known from only a single specimen that represents part of one volution of the conch, and therefore detailed comparisons are not possible. However, its ventral zone bears two longitudinal grooves, and in view of the fact that it is much older than the species under consideration, it is not probable that the two are closely related.

Occurrence.—About 100 feet above the base of the Bone Spring limestone near the mouth of Apache Canyon about 0.2 mile north of the Van Horn quadrangle on the second promontory north of the lower bench on the outside rim of the northern part of Apache Canyon in the Sierra Diablo of Hudspeth County, Texas.

Types.—Princeton University.

METACOCERAS MEGAPORUM Miller, n. sp.
Plate 45, figures 3, 4

The holotype of this species is an essentially complete well-preserved specimen about 50 mm. in diameter. Its conch, which consists of approximately two volutions, attains a maximum height of about 19 mm. and a corresponding width of about 24 mm. The length of the living chamber can not be determined, but it is at least one-third of a volution. The umbilicus of this specimen is about 22 mm. in diameter; and the subovate umbilical perforation is about 8.5 mm. long and about 6 mm. wide. The umbilical walls are very steep and are essentially perpendicular to the flattened lateral zones of the conch.

The adapical half of the first volution of the conch is rapidly expanded orad and is circular or nearly so in cross section. After the conch had completed half of a volution, it became abruptly flattened laterally, ventrally, and dorsally, and throughout ontogenetic development it remained almost square in cross section. However, before the conch had completed one full volution it became slightly concave dorsally and ventrally. The dorsal concave zone developed into an impressed zone in the adapical part of the second volution, but it is perhaps worth noting that the extreme adapical part (about 4 mm.) of the conch is not quite in contact with the following volution.

The adapical half volution of the conch bears prominent transverse growth lines and a slight ventrolateral ridge or raised line. At maturity, the growth lines are nearly straight on the umbilical walls, but they curve rather strongly apicad as they approach and cross the umbilical shoulders. On the dorsal part of the lateral zones their curvature is abruptly reversed, and they form a broad shallow rounded salient on the remainder of the lateral zones. On the ventral side of the conch they form a broad, deep, rather narrowly rounded sinus, a hyponomic sinus. At the adoral end of the first half volution, when the conch became more or less square in cross section, it developed a low, rounded dorsolateral keel, which became relatively larger throughout ontogenetic development but at no time was

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EXPLANATION OF PLATE 45

The specimens represented by figures 2–4 on this plate came from the Bone Spring limestone near the mouth of Apache Canyon in the Sierra Diablo of Hudspeth County, Texas; and they are in the collections of Princeton University. All of the other specimens illustrated are from the Leonard formation near Split Tank in the Glass Mountains of Brewster County, Texas; and they are the property of the U. S. National Museum.

FIGS. *1*—*Metacoceras mutatum* Miller, n. sp. Holotype, ×1. (p. 290)
2—*Metacoceras mammiferum* Miller, n. sp. Holotype, ×1. (p. 288)
3, 4—*Metacoceras megaporum* Miller, n. sp. Holotype, ×1. (p. 289)
5–8—*Metacoceras gregarium* Miller, n. sp. Three of the syntypes; *6* represents the adapical part of *5*; all ×1. (p. 286)
9, 10—*Metacoceras magnicostatum* Miller, n. sp. Holotype, ×1. (p. 287)
11, 12—*Metacoceras cooperi* Miller, n. sp. Holotype, ×1. (p. 285)

very prominent. At about the same time that it developed a dorsolateral keel, the conch developed abruptly a row of rounded ventrolateral nodes, prolongations of which extend out onto the lateral zones of the conch as short ribs. These nodes increased in prominence until the conch attained full maturity, but in the extreme adapical part of the holotype they seem to diminish. In the outer volution of the holotype there are twelve of these nodes or ribs.

Remarks.—In general physiognomy, this species resembles rather closely *Metacoceras cooperi* of the Leonard formation in the Glass Mountains. However, that form has a small umbilical perforation, whereas this one has a particularly large one. The size of the umbilical perforation seems to be one of the most distinctive characters of this species and suggested its name.

Occurrence.—About 100 feet above the base of the Bone Spring limestone near the mouth of Apache Canyon about 0.2 mile north of the Van Horn quadrangle on the second promontory north of the lower bench and on the outside rim of the northern part of Apache Canyon in the Sierra Diablo of Hudspeth County, Texas.

Holotype.—Princeton University.

METACOCERAS MUTATUM Miller, n. sp.
Plate 45, figure 1

This species is based on a single specimen that is exceptionally well preserved and almost complete—the adoral two-fifths of its outer volution represent living chamber. The conch consists of very slightly more than two full volutions, and its maximum diameter measures about 52 mm. Near the midlength of the outer volution, the conch is about 19 mm. wide and about 17 mm. high.

The umbilicus is large and open, and the maximum diameter measures about 23 mm. The umbilical perforation is subovate, about 6 mm. long, and 3.5 mm. wide. The umbilical walls are steep but not quite perpendicular to the flattened lateral zones of the conch. As in other representatives of this genus, the extreme adapical part of the conch is rapidly expanded and is almost circular in cross section. However, after the conch had completed approximately half of a volution, its shape changed abruptly. That is, it was somewhat expanded in a lateral direction, its lateral and dorsal zones became flattened, and its ventrolateral and dorsolateral zones became subangular and developed slight carinae. The ventrolateral carina was developed somewhat more abruptly than the inconspicuous dorsolateral one, and it becomes obsolete on the adoral quarter volution of the holotype.

In the adoral part of the second half volution of the conch, the dorsal zone becomes slightly but distinctly concave, simulating an impressed zone, which of course does not start until the conch has completed a full volution. The ventral zone of the conch is slightly convex except in the adoral half volution of the holotype, where it develops a rather prominent median groove some 6 or 7 mm. wide and at least 1 mm. deep. Also, in the adoral three-fifths of the outer volution of the holotype there is a shallow groove about 1 mm. wide near the midheight of the lateral zones.

For the most part, the growth lines are nearly straight and directly transverse on the umbilical walls, but as they approach the umbilical shoulders they curve apicad. On the lateral zones of the conch these growth lines are sigmoidal, and on the ventral zone they form a moderately deep rather broadly rounded sinus. On the adapical half volution of the conch the growth lines seem to be particularly prominent. The adapical one and one-third volutions of the conch do not bear more than a suggestion of lateral ribs. However, on the remainder of the holotype, that is, on the adoral two-thirds of its outer volution, low, rounded lateral plications are gradually developed, and these become very large and prominent in the adoral part of the holotype. They are much more prominent on the ventral half of the lateral zones than on the dorsal half. They end abruptly on the ventrolateral zones and can almost be said to form nodes there.

The siphuncle is small and is composed of cylindrical segments. Where the conch is about 16 mm. high, the siphuncle is about 1 mm. in diameter and is located about 5 mm. from the venter.

Remarks.—The most distinctive character of this species is the development of prominent lateral ribs and ventral and

lateral grooves on the adoral portion of an otherwise almost smooth conch. The adapical and the adoral half volutions of the holotype contrast strongly with the rest of it.

Occurrence.—Upper Leonard south of the road 0.2–0.5 mile east of Split Tank, 1.5 miles northeast of the bowed fork near the old Word Ranch house, about 19 miles north-northeast of Marathon, Brewster County, Texas.

Holotype.—U. S. National Museum, 111619.

Genus COOPEROCERAS Miller, n. gen.

G. A. Cooper's collection from the Middle Permian Word limestone of west Texas contains a unique specimen (pl. 44, figs. 3, 4) that appears to be related to *Metacoceras* but not to belong in it or in any other established genus. This specimen is rather small, and it is incomplete both adapically and adorally. Its adoral portion is much more strongly curved than is the adapical and comparison with typical representatives of *Metacoceras* indicates that it represents the adapical half volution of the conch (text fig. 1**A**). Apparently the umbilical perforation was fairly large. The cross section of the conch is more or less square, but the dorsal and the dorsolateral zones are broadly rounded (text fig. 1**B**). The ventrolateral zones bear long, slender hollow paired spines that project ventrolaterally—these are perhaps the most significant character of the genus. The septa are moderately convex, and almost certainly the sutures form shallow ventral and lateral lobes. The siphuncle is small and is located about midway between the venter and the center.

Insofar as I have been able to ascertain, the only previously described species that may belong in this genus is "*Metacoceras spinosus*" Kruglov of the Permian Artinskian beds of the Ural region (text fig. 1**C**). Kruglov's description and illustrations of that form indicate that in general physiognomy its conch is somewhat comparable to that of *C. texanum* and that at maturity it bore similar spines. If spines were present on the inner volutions of Kruglov's specimens he failed to detect them, but apparently the preservation of his type material left much to be desired. The angle of projection of the spines of *C. texanum* is such that they would not have interfered with the development of additional volutions, if as in *C.? spinosum* the conch did not expand orad very rapidly and at maturity the umbilical walls were not very steep.

Relatively short, rounded ventrolateral nodes or spines are present on such forms as *Metacoceras sinuosum* Girty of the Pennsylvanian Wewoka formation of Oklahoma, *M. mammiferum* of the Permian Bone Spring formation of Texas, and *M. dorsoarmatum* (Abich) of the Upper Permian of Armenia.

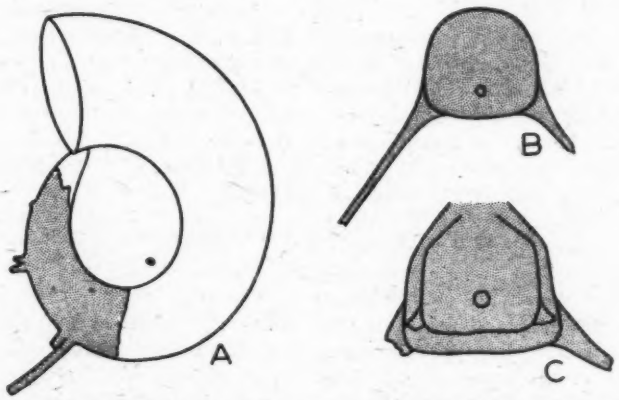

FIG. 1—Type specimens of *Cooperoceras texanum* Miller, n. sp. [**A, B**] and *C.? spinosum* (Kruglov) [**C**]. **A** indicates the probable relationship of the preserved part of the holotype of *C. texanum* to the rest of the conch, ×1. **B** represents a cross section through the adoral spines of this holotype, ×1½. **C** is after Kruglov, ×1.

However, in all of these species the ventrolateral protuberances are much more like the nodes on typical *Metacoceras* than the spines on *Cooperoceras*.

It should perhaps be mentioned that at Princeton University in Stanislaus Kříž's collections from the Bone Spring limestone in Apache Canyon of the Sierra Diablo, west Texas, there are several fragments of moderately large spinose specimens that may possibly belong in this genus. Unfortunately, all of them represent such small portions of the conch that their affinities can not be determined with any degree of certainty.

COOPERACERAS TEXANUM Miller, n. sp.
Plate 44, figures 3, 4

The specimen on which this species is based is a silicified replacement of about one-third of a volution of a coiled conch. The maximum length of this holotype, measured along the venter, is about 33 mm. The adoral portion of this specimen is much more strongly curved than is the adapical, as in the adapical half volution of typical representatives of *Metacoceras*. Apparently the umbilical perforation is considerably larger than in *Metacoceras*. The cross section of the conch is more or less square, but the dorsal and dorsolateral zones are broadly rounded; also the lateral zones appear to be very slightly converged dorsad. The maximum height and width attained by the preserved portion of the holotype measure about 11 mm. and 11.5 mm., respectively.

For the most part the surface of this specimen is smooth, but faint traces of growth lines indicate that they formed broadly rounded dorsal salients and ventral sinuses. Also, on the ventrolateral zones of the preserved part of the holotype there are the remains of three pairs of long, slender hollow spines. They are circular in cross section, they rise abruptly from the surface of the conch, and they extend obliquely outward and downward (ventrad). The most nearly complete of the spines is about 13 mm. long; near its base it is some 2 mm. in diameter, but at its broken distal end it is only about 1 mm. in diameter.

In the adapical part of the holotype, the camerae average a little less than 2 mm. in length. Apparently the sutures are not strongly sinuous, and the septa are moderately convex apicad. The siphuncle is small, circular in cross section, and is located about midway between the center and the venter.

Remarks.—Only one described species may be congeneric with the form under consideration, *Cooperoceras? spinosum* (Kruglov) of the Artinskian of the Ural region. Very little information is available in regard to the adapical portion of the conch of that species, and therefore detailed comparisons are not possible. However, because of the difference in age and geographic position of the strata that yielded the two forms, it is not probable that they are particularly close.

Occurrence.—Third limestone of the Word formation on the northern slope of the hill on the southern side of Hess Canyon about 4 miles N. 35° E. of the Hess Ranch house, some 14 miles north-northeast of Marathon, Brewster County, Texas.

Holotype.—U. S. National Museum, 111621.

STENOPOCERAS INEXPECTANS Miller, n. sp.
Plate 44, figures 5, 6

The type specimen of this species represents the inner, immature portion of the conch, and it resembles comparable portions of *S. abundum* Miller and Thomas of the upper Pennsylvanian Casper sandstone of Wyoming. The maximum diameter of the holotype under consideration is about 34 mm., and the maximum height and width of conch are about 20 mm. and 13 mm., respectively. In the adapical portion of the outer volution of this specimen the conch is rounded ventrally and flattened laterally, with the lateral zones diverging dorsad, and the height and width of the conch measure about 9 mm. and 10 mm., respectively. As ontogenetic development proceeds the conch becomes relatively higher and narrower, the ventral portion of it becomes more acuminate, and along the venter there is developed a flattened zone which at first is less than 1 mm. wide but at the adoral end of the holotype is about 2 mm. wide.

The umbilicus is small and the umbilical shoulders are rounded and therefore more or less indefinite. The maximum diameter of the umbilicus of the holotype is some 5 mm.

No trace of surface markings is preserved on the only known representative of this species. The septa are strongly curved dorsoventrally but only slightly so laterally. The siphuncle is small and is located about midway between the center and the venter.

Remarks.—Fragments of an outer volution or volutions adhere to the umbilical portions of the above-described holotype, and these indicate that at full maturity the umbilicus was probably closed. The genus *Stenopoceras* was previously known from the Pennsylvanian of Nebraska, Wyoming, New Mexico, and central European Russia, and from the Permian of Kansas and Texas. However, almost all of these described forms are mature specimens, and the only one with which the holotype under consideration can be compared satisfactorily is *S. abundum* Miller and Thomas. Comparable portions of the conchs of these two species are similar in general physiognomy, but the Wyoming form has a larger umbilicus and a different rate of adoral expansion. The representative of *Stenopoceras* from the Clyde formation near the "Old Military Crossing" in Baylor County, Texas, which White (1891, p. 24, pl. 2, figs. 4–6) illustrated and described is also similar to *S. inexpectans*.

Occurrence.—Upper Leonard south of the road 0.2–0.5 mile east of Split Tank, 1.5 miles northeast of the bowed fork near the Old Word Ranch house, about 19 miles north-northeast of Marathon, Brewster County, Texas.

Holotype.—U. S. National Museum, 111622.

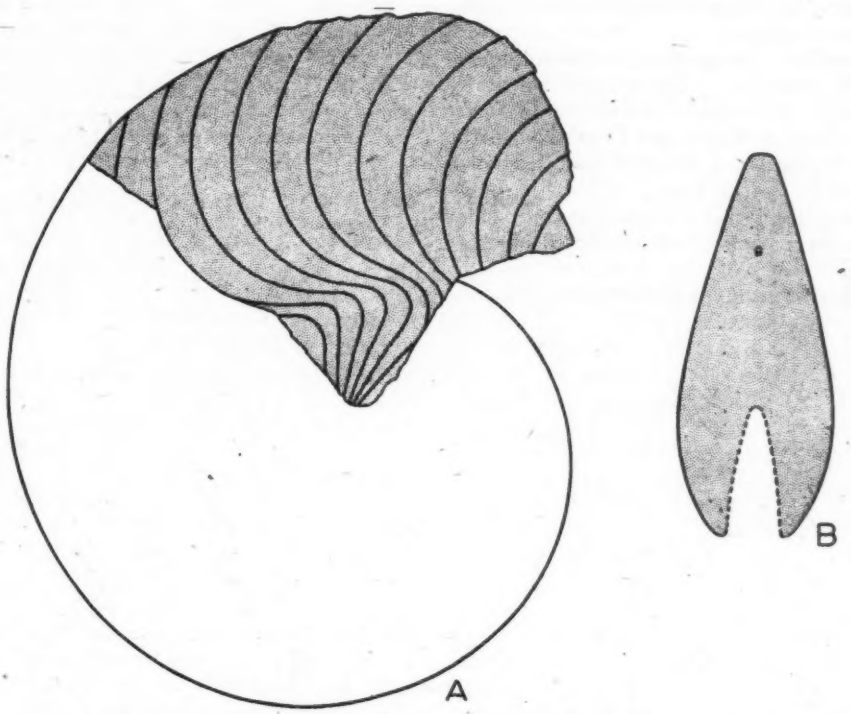

FIG. 2—Lateral view and cross section of *Stenopoceras* sp., from the Hueco formation in Apache Springs Canyon of the Sierra Diablo, Texas, ×1.

STENOPOCERAS sp.

Stanislaus Kříž's collections contain a fragment of a typical representative of *Stenopoceras* that does not seem to be referable to any described species but is too incomplete and distorted to serve satis-

factorily as the type of a new species. This specimen represents about one-fourth of a volution of a phragmacone. Near its adapical end its conch is about 53 mm. high and about 21 mm. wide, and the flattened ventral zone is about 5 mm. wide. The maximum width is attained in the vicinity of the umbilical shoulders, which are indefinite. The shape of the sutures, the cross section of the conch, and the size and position of the siphuncle are shown by the accompanying illustrations, figure 2.

Remarks.—The specimen under consideration is preserved in fine-grained light-gray limestone. It resembles rather closely *Stenopoceras cooperi* Miller and Unklesbay of the Neva limestone of Kansas, but that form has a wider ventral zone.

Occurrence.—Basal limestones and shales in the lower part of a downfaulted block of the Lower Permian Hueco formation on the south branch of Apache Springs Canyon in the Sierra Diablo of Hudspeth County, Texas.

Repository.—Princeton University.

MANUSCRIPT RECEIVED JANUARY 29, 1944.

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JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, PP. 295–308, PLS. 46, 47, MAY 1945

PROTODONAX, A NEW CRETACEOUS MOLLUSCAN GENUS

H. E. VOKES
U. S. Geological Survey, Washington, D. C.

IT HAS long been recognized that the genus *Donax*, together with its subgenera, essentially is confined to the Tertiary and Recent faunas (Stoliczka, 1870, p. 135); and Stewart states (1930, p. 205): "The genus—even in the broad sense—is, I believe, unknown before the Tertiary." It was, therefore, the occasion for some surprise to find strong donacid affinities in the hinge of a topotype specimen of the Lower Cretaceous (Aptian) species which had been described as *Donax minutissimus* by Whitfield (1891, p. 411, pl. 7, figs. 12, 13) from the fauna of the "Olive Locality" at Abeih, Republic of Lebanon. Investigation shows, however, that this species is not to be referred to *Donax*, but has characters which seem to be somewhat ancestral to that genus. It is, instead, considered as a member of a new genus, *Protodonax*, whose genotype species is *Protodonax elongatus*, n. sp., from the Colorado group of the American interior Cretaceous.

An examination of the Cretaceous collections in the United States National Museum reveals that this new genus is surprisingly well represented in the faunas from the North American midcontinent region. Eleven, and possibly 12, species are recognized from that area, eight, and possibly nine, being from deposits referred to the Colorado group, and three from the Montana group. In addition, the genus is present in the fauna of the Atlantic Coastal area, "*Donax?*" *atlantis* Stephenson dredged from Georges Bank on the Continental Shelf being a *Protodonax*.

Two of the 11 species from the Western Interior Cretaceous, which are assigned to *Protodonax*, have been previously described: "*Donax*" *oblonga* Stanton (1893, p. 111, pl. 25, fig. 2) being from the Colorado group and "*Tellina*" *maylandensis* Landes (1940, p. 159, pl. 5, figs. 13, 14) from the Montana group. A third described species, "*Donax*" *cuneata* Stanton (1893, p. 110, pl. 25, fig. 1) is probably a representative of this genus, but available material is not sufficient to permit any certain conclusions.

Recent collections made by Dr. L. W. Stephenson, from the Lewisville formation of Texas, contain two or three species referable to this genus. They are the only forms yet known from the Gulf Coastal Plain Cretaceous deposits, and will be described by Dr. Stephenson in his forthcoming memoir on that fauna.

Genus PROTODONAX Vokes, n. gen.

Type species: *Protodonax elongatus*, new species. Cretaceous, Colorado group, Wyoming.

The species referred to this genus are donaciform in outline, smooth externally, and characterized by the presence of a definite angulation of the valve surface along a line extending from immediately posterior to the umbone to the posterior ventral corner, which is, also characteristically, rather sharply angulate. The strength of the angulation on the valve surface varies in different species, being exceedingly sharp, almost carinate, in some forms (*P. minutissimus* (Whitfield), *P. magnus*, n. sp., and *P. sphenicus*, n. sp.), more rounded in the genotype, and in *P. maylandensis* (Landes), and even relatively low and broadly rounded in *P. atlantis* (Stephenson). In this latter species, the most extreme example of the reduction of the angulation at present known, this feature is, however, still sufficiently well developed to be a distinctive character. Internally the margins of the valve are smooth, not denticulate as in *Donax*, and the pallial line is sinuate, forming a small, right-angled indentation very different from the deep, U-shaped sinus of *Donax* and *Tellina*.

The hinge of the left valve has well-developed anterior and posterior laterals, the former being generally thin and markedly elongate, extending almost the full length of the anterior dorsal margin of the valve; the posterior being shorter, somewhat heavier, and in some species at least, transversely striated. There are two cardinals in this valve; the anterior heavy, trigonal, and often somewhat elongated anteriorly; the

posterior thin, almost lamellar and fused throughout part (*P. minutissimus*, *P. elongatus*) or all (*P. sphenicus*) of its length to the anterior end of the wide but short, somewhat excavated nymph plate.

The hinge of the right valve is not as well known as that of the left. There are anterior and posterior paired lateral teeth, the laterals of the left valve being received in the deep socket separating them. The dorsal lateral of each pair is adjacent to the valve margin, being separated from it by a shallow, linear groove, and is somewhat smaller than the ventral tooth. There seem to be two cardinals, the posterior relatively heavy and trigonal, the anterior thin and so reduced as to be almost lost, being apparently fused with the dorsal margin of the valve.

The relationships of this genus are not entirely clear. In shape and, to a certain extent, in hinge structure, it seems to be ancestral to *Donax*, although the strikingly different pallial sinus and the absence of denticulation along the valve margin would seem to cast some doubt upon this assignment. Qualification as to the hinge structure is based upon the fact that no adequate right hinge has been available for study, and there is doubt as to the nature of the anterior cardinal in that valve, but there seems to have been a narrow cardinal adjacent to, and subparallel with, the anterior dorsal margin. This condition has been reported by Cox (1929, p. 578) in *Corbicellopsis laevis* (Sowerby), the type of *Corbicellopsis* Cox. This genus, which is referred to the Tancrediidae, is apparently confined to the Jurassic faunas. It has a pallial sinus quite similar to that of *Protodonax*, the internal margins are smooth, and the hinge is like that of the present genus except that there is no anterior lateral tooth. Most of the known species attain a larger size than do those of *Protodonax*, and the umbones are subcentral. There is generally a moderately prominent posterior umbonal ridge, but the valves seem never to be sharply angulate, as in the present forms.

Corbicellopsis is very closely related to the genus *Tancredia* Lycett (1850, pp. 407, 424). This latter genus, known to occur from the Upper Triassic to the Upper Cretaceous, tends to have the left posterior and the right anterior cardinal teeth reduced or often entirely obscured, and also to possess a distinct posterior gape in the valve margins.

EXPLANATION OF PLATE 46

FIGS. *1–6*—*Protodonax elongatus* Vokes, n. gen., n. sp. *1*, Hinge of left valve, ×4, holotype, U.S.N.M. 103718; *2*, hinge of right valve, ×4, paratype, U.S.N.M. 103719; *3*, right valve, ×1½, paratype, U.S.N.M. 103719; *4*, left valve, ×1½, holotype U.S.N.M. 103718; *5*, left valve. ×1½, paratype, U.S.N.M. 103719; *6*, dorsal view of holotype, ×1½, U.S.N.M. 103718. (p. 298)

7, 8—*Protodonax sphenicus* Vokes, n. sp. *7*, Left valve, ×1½, holotype, U.S.N.M. 103724; *8*, hinge of left valve, ×4, paratype, U.S.N.M. 103725. (p. 300)

9, 10—*Protodonax stantoni* Vokes, n. sp. *9*, Left valve, ×4, holotype, U.S.N.M. 103722; *10*, mold of interior of right valve, ×1½, paratype, U.S.N.M. 103723. (p. 299)

11—*Protodonax chloropagus* Vokes, n. sp. Right valve, ×1¼, holotype, U.S.N.M. 103737. (p. 305)

12, 13—*Protodonax maylandensis* (Landes). *12*, Left valve, ×1½; *13*, right valve, ×1½. Hypotypes, U.S.N.M. 103733. (p. 304)

14—*Protodonax? cuneatus* (Stanton). Right valve, ×1½, figured specimen (paratype?), U.S.N.M. 103732. (p. 303)

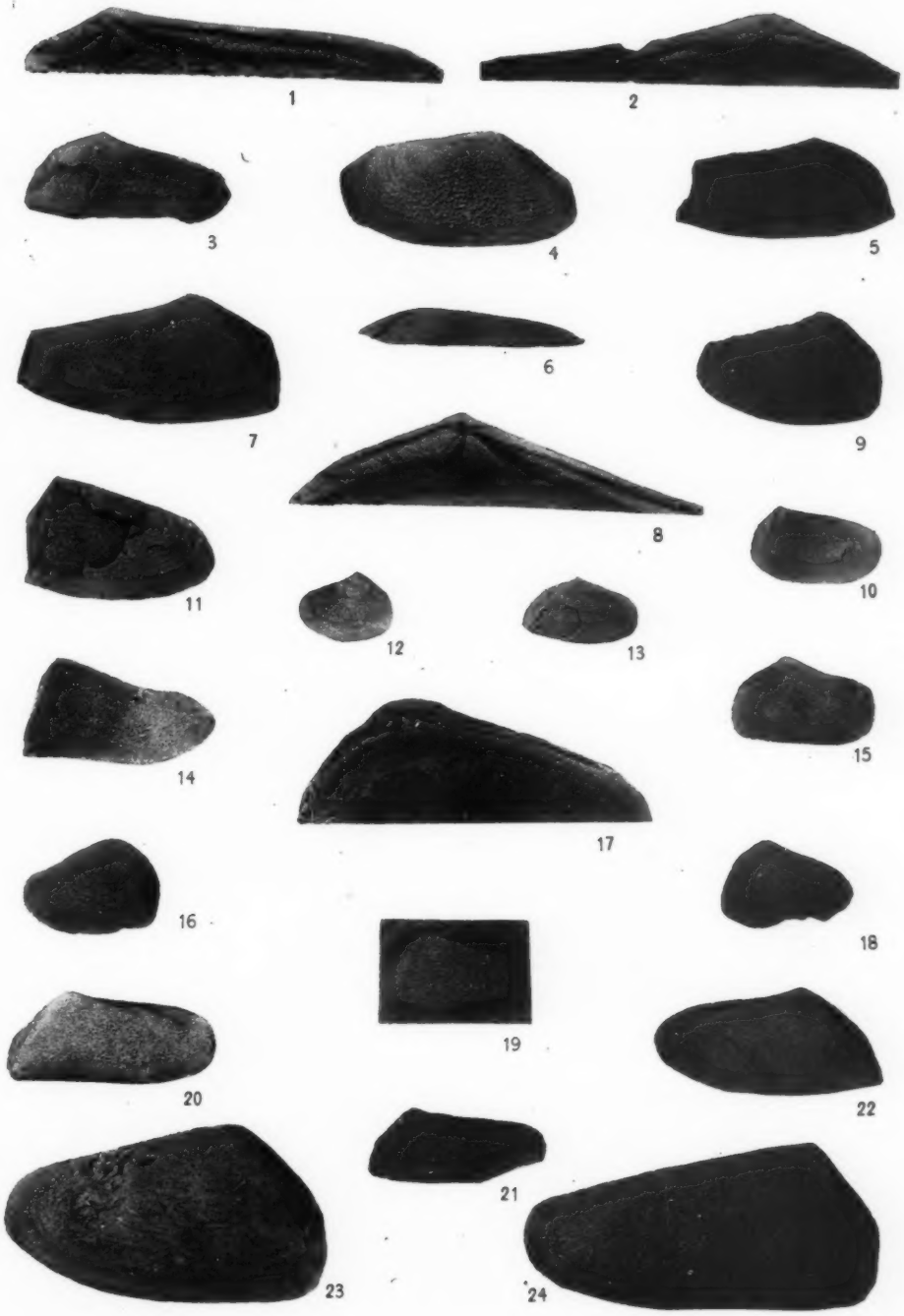
15—*Protodonax coalvillensis* Vokes, n. sp. Mold of interior of right valve, ×1½, holotype, U.S.N.M. 103731. (p. 303)

16–18—*Protodonax minutissimus* (Whitfield). *16*, Left valve, ×1½, topotype, A.M.N.H. 25988:1; *17*, hinge of left valve, ×4, topotype, A.M.N.H. 25988:2; *18*, right valve of holotype, ×4, A.M.N.H. 1640011. (p. 307)

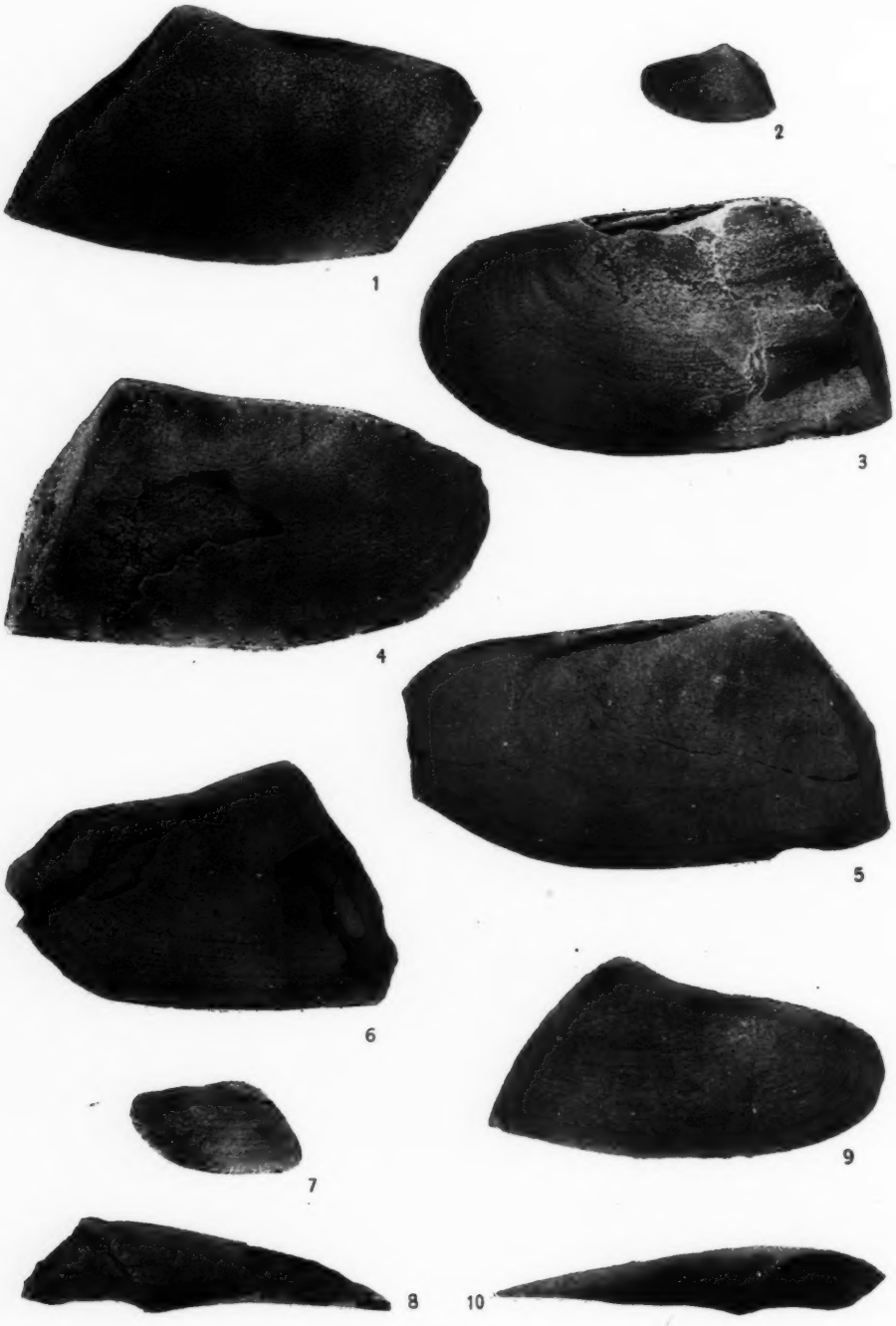
19—*Protodonax* Vokes, n. sp. (*exaquilius* var.?). Mold of interior of right valve, ×1½, U.S.N.M. 103736. (p. 305)

20–22, 24—*Protodonax exaquilius* Vokes, n. sp. *20*, Mold of interior of right valve, ×1½, holotype, U.S.N.M. 103734; *21*, mold of interior of right valve, ×1½, paratype, U.S.N.M. 103735; *22*, mold of interior of left valve, ×1½, paratype, U.S.N.M. 103735; *24*, mold of interior of left valve, ×1½, paratype, U.S.N.M. 10738. (p. 304)

23—*Protodonax atlantis* (Stephenson). Squeeze of holotype, an external mold of a left valve, ×1½, M.C.Z. 15114. (p. 306)



Vokes, *Protodonax*



Vokes, *Protodonax*

There is considerable variation in the strength of this gape, in some species it is relatively small, in others strongly pronounced. As with *Corbicellopsis*, the anterior lateral tooth is absent.

Thus, in some features *Protodonax* seems more closely allied to *Corbicellopsis*, referred to the family Tancrediidae, than it is to to *Donax;* in other features, however, it is clearly allied to *Donax*, and is here provisionally considered to be a member of the family Donacidae. It may well prove to be a connecting link between the two families.

The genus *Isodonta* Buvignier (1851, p. 353), which Dall (1899, 1913), following Zittel (1879, 1895), considered as representing the oldest member of the Donacidae has recently been removed to a separate family by Cox (1929a, p. 192) and Arkell (1934, p. 309). The generic name *Isodonta* seems to be a synonym of *Sowerbya* d'Orbigny (1850; see discussion in Arkell, 1934 and Opinion 126, International Commission on Zoological Nomenclature). The genus has a single median cardinal in the left valve with two elongate cardinal teeth in the right. Each valve has two very strong, elongate, horizontally placed lateral teeth. The pallial sinus is moderately deep. Arkell (1934) speaks of a ligamental pit separating the two cardinal teeth of the right valve. The illustrations are not clear, but this "ligamental pit" seems rather to be the socket for the left cardinal, and there is no mention of any structure on the left hinge for the reception of a ligament. If, however, the ligament was internal, *Isodonta* (=*Sowerbya*) could not be considered ancestral to the Donacidae.

The distribution of the species of *Protodonax* seems to have been controlled primarily by ecologic factors. As at present known, it appears to have been almost exclusively a representative of the shallow-water, near-shore fauna which is present only in areas of sandy bottom. This is also the preferred environment of species of *Donax*, and might be considered as further evidence suggestive of the ancestral position of the present genus.

This interpretation of the environmental factors favored by *Protodonax* is based upon the geographical distribution of the known occurrences of the species of the genus, the matrix in which they are found, and on the associated faunas. The several species found in the faunas of the Colorado group are known only from New Mexico, Utah, and western Wyoming, areas which were near the margins of the Cretaceous seaway. Here they are almost exclusively found in association with such species as *Ostrea soleniscus* Meek, *Volsella multilinigera* (Meek), *Cardium pauperculum* Meek, *Barbatia micronema* (Meek), *Mactra utahensis* Meek, and *Corbula nematophora* Meek. These species, with variable associates, form a fauna that recurs at a number of horizons throughout the Colorado group in a distribution that is obviously controlled by ecologic factors.

In the Montana group the genus is represented in the fauna of the Virgelle sandstone in Montana, being known only from localities which represented the westernmost incursion of the lower Montana seaway. It is also present in the extreme southern portion of Alberta, being found at the base of the Foremost formation. The strata of this horizon may be interpreted as representing the sands deposited along the shore in one of the retreats of the Montana sea from this

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EXPLANATION OF PLATE 47

All figures ×1½

FIGS. *1, 2—Protodonax oblongus* (Stanton). *1*, Squeeze of external mold of right valve, hypotype, U.S.N.M. 103721; *2*, mold of interior of left valve, topotype (paratype?), U.S.N.M. 103720. (p. 298)

3–5—Protodonax magnus Vokes, n. sp. *3*, Exterior of left valve, holotype, U.S.N.M. 103726; *4*, exterior of right valve, paratype, U.S.N.M. 103727; *5*, mold of interior of left valve, holotype, U.S.N.M. 103726. (p. 301)

6–8—Protodonax datilensis Vokes, n. sp. *6*, Exterior of left valve, holotype, U.S.N.M. 103729; *7*, exterior of left valve of juvenile specimen, paratype, U.S.N.M. 103730; *8*, dorsal view of holotype, U.S.N.M. 103729. (p. 302)

9, 10—Protodonax umbonianus Vokes, n. sp. *9*, Exterior of right valve, holotype, U.S.N.M. 103728; *10*, dorsal view of holotype, U.S.N.M. 103728. (p. 301)

area, the overlying sands of the Foremost being almost wholly of brackish and freshwater deposition.

It seems possible that the restriction to the shallow-water sandy environment may be a factor explaining the large number of species encountered during this study. Variations in the nature of the bottom deposit, in salinity of the sea water, and similar ecologic factors along the shore would serve as barriers controlling the distribution of the species and permit the evolution of many relatively localized species distinct from other, geographically not far distant, members of the same genus.

SPECIES FROM THE COLORADO GROUP

PROTODONAX ELONGATUS Vokes, n. sp.

Plate 46, figures 1–6

Holotype, U.S.N.M. 103718; length (slightly incomplete anteriorly) 21.4 mm.; height 10.5 mm.; diameter (left valve) 3.2 mm.

Paratype, U.S.N.M. 103719; length (slightly incomplete anteriorly) 20.4 mm.; height 9.6 mm.; diameter (left valve) 2.9 mm.

Paratype, U.S.N.M. 103719; length 20.2 mm.; height (slightly incomplete) 7.9 mm.; diameter (right valve) 2.7 mm.

Description.—The shell is relatively small, elongate-donaciform with the anterior end of the valve produced. The umbones are low and situated approximately at the posterior third of the length of the valve. The anterior dorsal margin is slightly concave, almost straight, the anterior broadly and regularly rounded, the ventral but slightly convex, being sharply angulate at the posterior end where it joins the posterior margin. The length of this margin is approximately half the height of the valve; it is straight with the dorsad end being slightly anterior to the ventral end. The anterior dorsal margin is very slightly convex.

The surface of the valve is smooth, being ornamented only by lines of growth which tend to be somewhat more prominent on the posterior slope than they are on other portions of the valve. This posterior slope is delimited anteriorly by a prominent but slightly rounded angulation extending from the umbone to the posterior ventral margin. The trend of this angulation forms an angle of 38° to 40° from the horizontal as determined from the length of the valve.

The hinge and pallial sinus are typical of the genus as described above. The inner margins of the valves are smooth. The anterior muscle scar is almost circular, relatively large, impressed and rugose, the posterior adductor scar is likewise large and impressed, being pointed anterodorsally, and rounded below. Some, but not all casts of this species show a low, broad subumbonal ridge or buttress extending slightly anteroventrally from a position just inside the umbone to a point approximately one-third the height of the valve.

Locality and horizon.—Known only from 20 miles west of Douglas, Converse County, Wyoming, in the SE¼ sec. 18, T. 33 N., R. 74 W. of the 6th Prime Meridian. From the Colorado group of the Upper Cretaceous. The fauna indicates a horizon approximately equivalent to that of the Carlile shale.

Remarks.—The general anterior elongation with the relatively straight and subparallel anterior dorsal and ventral margins will serve to distinguish this species from most other forms referred to this genus. The broadly and regularly rounded anterior end, the rather low angle of trend of the surface angulation, which is also more rounded than in most species, and the slightly anterior trend of the straight posterior margin are also characteristic of this form. It will be specifically compared with other species below.

PROTODONAX OBLONGUS (Stanton)

Plate 47, figures 1, 2

Donax? oblonga STANTON, 1893, p. 11, pl. 25, fig. 2; Stanton, 1899, p. 638.

Donax cuneata STANTON, 1899, p. 638.

Donax oblonga STANTON, HENRICK, and JOHNSON, 1900, pl. 40, fig. 2.

Topotype (unfigured paratype) U.S.N.M. 103720; length 11.7 mm.; height 7.5 mm.; diameter (internal mold, left valve) 2.1 mm.

Hypotype, U.S.N.M. 103721; length (slightly incomplete anteriorly) 43.6 mm.; height 25.3 mm.; diameter (cast of right valve) 5.2 mm.

Stanton's original description of this species is as follows:

Shell rather large, moderately convex, transversely oblong, with the short posterior end obliquely truncate; dorsal and ventral margins nearly parallel; anterior end produced, broadly rounded at the extremity with the greatest con-

vexity of the curve above; posterior umbonal slope prominent and angular, varying considerably in obliquity, but always more oblique than in *D. cuneata;* beak rather prominent, incurved. Surface and hinge unknown. The casts show a few distant concentric furrows.

Remarks.—Stanton's type of this species has not been available for examination. However, the species is rather abundantly represented in the collections, the material available including the six smaller topotype specimens mentioned by Stanton in the discussion which followed his description, cited above. The majority of the specimens examined are small, similar to that shown on plate 47, figure 2.

There is a considerable degree of difference in proportion between the immature representatives and the adult specimens. In general the truncated posterior margin is relatively longer, the posterior end somewhat longer, the umbones being slightly anterior to the posterior third of the length in the young specimens, and slightly posterior to the distance in the adults. As a result the degree of obliquity of the posterior umbonal angulation is somewhat greater in the young, trending at an angle of 50° to 55° in the more immature representatives, and about 58° in the adult individuals.

External molds show that the surface of the shell was smooth, and the internal molds reveal anterior and posterior laterals of the same general shape and proportions of those observed in other species of the genus. The characteristic type of pallial sinus is clearly represented, the internal margins are smooth and the adductor scars are of the usual relative size and shape.

Adult specimens of this species are larger than those of any other at present known; the only other form approaching them in this respect, *P. magnus,* will be compared below. *Protodonax elongatus,* n. sp., is much smaller, and differs from the immature representatives of *P. oblongus* in being much longer in proportion to its height, and in the more regularly rounded anterior end, in which the greatest convexity of the curve is approximately at the midlength of the arc. In addition, the umbones are lower and somewhat less inflated. The small subumbonal ridge, present in some specimens of the genotype species, has not been observed in any of the examples of *P. oblongus*

Locality and horizon.—Described from the "second ridge" at Coalville, Utah [zone no. 3 in the section given by Stanton (1893, p. 38) and no. 9 of that given by Wegemann (1915, p. 163)]. The faunas from this zone indicate an upper Carlile age, according to John B. Reeside, Jr. (personal communication). Also represented in collections from the "third ridge" on Grass Creek, near Coalville, Utah (of Niobrara age); in collections from the second crossing of the Snake River, Yellowstone National Park, Wyoming[1] (of Niobrara age); from the middle portion of the Hilliard formation, 1½ miles northwest of Kemmerer, Wyoming, N½ sec. 10, T. 21 N., R. 116 W. (of Niobrara age); in collections from sec. 31, T. 15 N., R. 118 W., just west of Carter Oil Spring, about 9 miles east-southeast of Evanston, Wyoming (of Carlile or Niobrara age); (?) from the center of sec. 23, T. 34 N., R. 116 W., Lincoln County, Wyoming (of Niobrara? age).

PROTODONAX STANTONI Vokes, n. sp.
Plate 46, figures 9, 10

Holotype, U.S.N.M. 103722; length 6.6 mm.; height 3.9 mm.; diameter (left valve) 1.2 mm.

Paratype, U.S.N.M. 103723; length (an internal mold of right valve) 10.7 mm.; height (slightly incomplete) 5.7 mm.; diameter 1.8 mm.

Description.—The shell is typically donaciform, relatively small, with umbones situated approximately at the posterior fourth of the length, moderately inflated and relatively high. The anterior dorsal margin is long and slightly concave, the anterior margin broadly and regularly rounded, and the ventral margin gently and evenly convex, but sharply angulate at the posterior end where it meets the moderately short, almost straight, truncate posterior end, which rounds, dorsally, to the short concave posterior dorsal margin. The surface of the valve is smooth, ornamented solely by lines of growth; where the surface has been eroded, however, an underlying radial "ornamentation" consisting of closely set striations may be observed. The posterior umbonal surface angulation is moderately

[1] The specimens from this locality were identified by Stanton (1899, p. 638) as including both "*Donax?*" *oblonga* and "*D.*" *cuneata.*

strong and trends at an angle of 65° to the horizontal, as determined from the length of the valve.

The pallial line, inner margins and adductor scars are typical of the genus. A fragmentary right hinge shows typically paired anterior and posterior laterals, with a moderately heavy posterior cardinal; the anterior cardinal seems to have been fairly well developed.

Remarks.—This species, of which only the types are known, is dedicated to Dr. Timothy W. Stanton, who collected the specimens described. It differs from *P. elongatus* in its relative proportions, the higher, more posteriorly located umbone being particularly distinguishing. The obliquity of the surface angulation is much greater even than that of the adult examples of *P. oblongus*, and the greatest convexity of the evenly rounded anterior end occurs at about midheight.

Locality and horizon.—The types, the only known examples, were collected at Old Bear River City, Wyoming, from strata which are probably of upper Carlile or Niobrara age. (See discussion of *P.? cuneatus* (Stanton).)

PROTODONAX SPHENICUS Vokes, n. sp.

Plate 46, figures 7, 8

Holotype, U.S.N.M. 103724; length (slightly incomplete anteriorly) 23.8 mm.; height 11.4 mm.; diameter (left valve) 5.0 mm.

Paratype, U.S.N.M. 103725; fragmentary left valve.

Description.—The shell is of moderate size, elongate-donaciform, with the anterior end produced, narrowed, and sharply convex in outline. The anterior dorsal margin is slightly concave, almost straight and gently sloping; the ventral margin is broadly convex, much higher anteriorly than posteriorly, meeting the moderately long, somewhat convex posterior end in a sharp angle; the posterior dorsal margin is relatively long, slightly convex, almost straight. The umbones, situated at the posterior third of the length, are relatively small but high and fairly prominent. The valve is rather strongly inflated at about midheight just posterior to the umbone and slopes to the sharply compressed anterior end. The surface angulation is pronounced, very sharp and almost carinate, trending at an angle of 50° to the horizontal, as determined from the length of the valve.

A fragmentary hinge of a left valve displays a moderately heavy trigonal anterior cardinal and a relatively thin, lamellar posterior cardinal, which is fused to the broad, heavy nymph plate throughout its entire length. The anterior lateral tooth is moderately thin and elongate; the posterior lateral quite short and heavy. No right hinge is known, but judging from the rather broad, well-developed anterior cardinal socket of the left valve the right hinge must have been unique in having a strong anterior cardinal tooth, which was heavier than the posterior cardinal. Pallial line, adductor scars, and inner margins of the valve unknown.

Locality and horizon.—Known only from the type specimens, which are on the same block of sandstone, and from the external mold of the holotype, collected from the Hilliard formation in the lowest group of sandstone ledges, near the middle of the formation, from the SE¼ sec. 34, T. 22 N., R. 116 W., about 3 miles north of Kemmerer, Wyoming (of Niobrara age). The types of *P. magnus*, n. sp., are from the same locality.

Remarks.—The sharp surficial angulation, the narrowed, cuneate anterior end, and the broadly convex ventral margin are the most distinctive features of this species. The equally elongate anterior end of *P. elongatus* is characterized by its relative width and broadly rounded termination, while in the present form it is strikingly narrowed and sharply rounded. *Protodonax magnus*, which occurs with *P. sphenicus*, is much larger, proportionately higher, with a broader anterior end, a more steeply inclined surface angulation, and, as a result, a shorter posterior end. *Protodonax minutissimus* (Whitfield), which has an almost equally acute surface angulation is proportionally much higher, relatively shorter, and the angulation trends at approximately 70° to 72° to the horizontal.

PROTODONAX MAGNUS Vokes, n. sp.

Plate 47, figures 3–5

Holotype, U.S.N.M. 103726; length 45.2 mm.; height 25.0 mm.; diameter (left valve) 7.8 mm.

Paratype, U.S.N.M. 103727; length (slightly incomplete) 43.4 mm.; height 23.0 mm.; diameter (right valve) 7.7 mm.

Description.—The shell is large for the genus, elongate-donaciform, and moderately inflated. The umbones are low, not prominent, and situated at the posterior fourth of the length of the valve. The anterior dorsal margin is broadly concave posteriorly, becoming slightly convex anteriorly before rounding into the rounded anterior end, which in turn passes gradually into the broadly convex anterior portion of the ventral margin; posteriorly this latter margin becomes almost straight. The posterior ventral corner is sharply angulate, the posterior very long and broadly convex, while the posterior dorsal margin is short and concave with a steep ventral slope. The surface of the valve is smooth, ornamented only by lines of growth; the posterior umbonal angulation is sharp and pronounced, trending at an angle of 66° to the horizontal as determined from the length of the valve, and the short posterior end drops abruptly at an angle of almost 70° from the plane of the anterior portion of the valve.

The hinge of this species is not well known. Internal molds of the left valve, however, reveal that the anterior lateral was of normal length, but was surprisingly heavy, being considerably stronger than the short posterior lateral. The nymph plate is also small and short, both it and the posterior lateral being crowded by the shortened posterior dorsal margin. The posterior cardinal seems to have been fused to the nymph plate throughout its entire length, and the anterior cardinal seems to have been of normal strength. The socket between these two cardinals is narrow, indicating that the posterior cardinal of the right valve must have been narrower and much less trigonal than is usual in this genus. The strong anterior cardinal is immediately bordered along its anterior ventral margin by the dorsal side of the impressed anterior adductor muscle scar. This would seem to indicate that this muscle would interfere with the normal development of the ventral anterior lateral of the right valve and that that tooth must have been shortened, extending only to the posterior end of the muscle, a condition quite similar to that observed in *P. atlantis* (Stephenson), described below.

The pallial line is well impressed, unusually distant from the valve margins, but typical in all other respects. The adductor scars are well impressed, of normal shape and proportions.

A well-developed, broad, and rounded subumbonal ridge is present on the interior of the valves, trending slightly anteroventrally from a point slightly in front of the tip of the umbone, and extending almost to the midheight of the valve, terminating immediately above the point of the pallial sinuation.

Locality and horizon.—Known only from the type locality, in the lowest group of sandstone ledges near the middle of the Hilliard formation, from the SE¼ sec. 34, T. 22 N., R. 116 W., about 3 miles north of Kemmerer, Wyoming, where it is associated with *P. sphenicus*, n. sp. The fauna from this locality is of Niobrara age.

Remarks.—The large size attained by this species is distinctive, the only form attaining comparable dimensions being the fully adult specimens of *P. oblongus* (Stanton). From that form, the present species may be distinguished by the steeper trend of the posterior umbonal angulation, the more posterior umbones and resulting shorter posterior end, the more elongate, relatively lower proportions of the valves, and in the internal molds, by the presence of the subumbonal ridge and the pallial line, which is more distant from the valve margins. It differs in all details of its shape from *P. sphenicus*, with which it is associated.

PROTODONAX UMBONIANUS Vokes, n. sp.

Plate 47, figures 9, 10

Holotype, U.S.N.M. 103728; length 34.5 mm.; height 18.8 mm.; diameter (right valve) 5.8 mm.

Description.—The shell is relatively large,

elongate, with a relatively high, moderately inflated umbone situated just behind the posterior third of the valve. The anterior dorsal margin of the valve is markedly concave along its posterior halflength, becoming slightly convex anteriorly. The anterior end is broadly rounded, with the greatest convexity of the arc slightly dorsad of the mid-height; the ventral margin is gently convex, sharply angulate to the posterior end, which is gently concave above and below a median convexity. The posterior dorsal margin is short and almost straight. The surface of the valve is smooth, marked only by lines of growth; near the anterior end of the shell these tend to be somewhat raised, suggestive of a form of concentric ornamentation, which, however, is not present over most of the surface of the valve. Where the shell is worn, there are microscopic traces of an underlying radial structure, similar to that better observed on the holotype of *P. stantoni*. The posterior umbonal angulation is strong and acute, being accentuated by a shallow concavity of the shell surface immediately posterior to the angulation. This concavity is paralleled, posterodorsally, by a low, broadly rounded ridge extending to the middle of the posterior margin. This ridge causes the median convexity of the margin noted above. The umbonal angulation has a trend of 53° from the horizontal.

Locality and horizon.—Known only from the Datil coal field, Socorro County, New Mexico. Two specimens are in the collection from the type locality, which is in the Miguel formation, immediately below the Gallego sandstone member, collected from the NE¼ sec. 31, T. 2 N., R. 5 W. The fauna from this locality suggests a Carlile age for the species. A third specimen may be represented by a poorly preserved internal mold collected from the NE¼ SW¼ sec. 24, T. 3 N., R. 7 W., north of Medley's Ranch, with an associated fauna suggesting a Greenhorn age.

Remarks.—The matrix in which the holotype is preserved proved too refractory to permit the development of the hinge and internal characteristics. It could only be observed that there were two rather short and moderately thin posterior lateral teeth, and that the nymph plate seems to have been rather short and probably moderately heavy. These observations, together with the characteristic external shape, seem to validate the generic reference to *Protodonax*.

The species is distinguished primarily by the high, protruding umbone, which is much more prominent than that of any of the other species known. The presence of a low, rounded secondary ridge extending to the median portion of the posterior margin is also a feature not observed on other specimens.

PROTODONAX DATILENSIS Vokes, n. sp.
Plate 47, figures 6–8

Holotype, U.S.N.M. 103729; length (incomplete) 35 mm.; height 22.2 mm.; diameter (left valve) 8.5 mm.

Paratype, U.S.N.M. 103730; length 15.8 mm.; height (slightly incomplete) 9.5 mm.; diameter (left valve) 4.0 mm.

Description.—The shell is relatively large, proportionally short, and unusually high and inflated, with moderately high umbones situated just behind the posterior third of the length of the valve. The anterior dorsal margin is moderately concave and is sharply rounded, almost subangulate to the anterior end, which has a broadly convex postero-ventral trend toward the almost straight ventral margin. The most anterior point of the valve occurs at about the dorsal third of the height of the anterior end. The posterior margin is not well preserved on the specimens available; it seems to have been broadly concave, almost straight; the posterior dorsal margin was broadly concave. The surface of the valve was smooth, ornamented only by lines of growth. The posterior umbonal angulation is very sharp and carinate, the carina being produced posteriorly and somewhat overhanging the posterior slope of the valve.

Locality and horizon.—Known only from the type locality, NE¼ sec. 31, T. 2 N., R. 5 W., from the Miguel formation, just below the Gallego sandstone member, Datil coal field, Socorro County, New Mexico. Here it is associated with *P. umbonianus*, n. sp., in a fauna believed to be of Carlile age.

Remarks.—The refractory matrix prevented the exposure of the hinge of either of the type specimens. It could be observed, however, that the anterior cardinal of the holotype, a left valve, was of the usual

elongate form, and that the nymph plate was relatively quite elongate, occupying approximately one-half the length of the posterior dorsal margin. This would suggest a somewhat shorter posterior lateral tooth than is present in most species of the genus.

The types of this species occur in the collections from the same locality as the types of *P. umbonianus*, n. sp. The type specimens differ, however, both in relative outline, proportions and in surface details. *Protodonax umbonianus* is longer, lower, and less inflated than *P. datilensis*, with a more prominent umbone, and a regularly rounded anterior end instead of the sharper, subpointed type, which is a unique character of the present species. The prominent surface angulation on both species trends at 53°, but in *P. datilensis* it is developed into a posteriorly projecting carina, lacking in *P. umbonianus*, in which species there is a subsidiary, parallelling rounded ridge extending to the median portion of the posterior border. Adult specimens of *P. oblongus* (Stanton) have a somewhat similar appearance, but may be distinguished from *P. datilensis* by their less inflated valves, relatively lower, less projecting umbones, more rounded anterior ends, broadly convex, rather than straight ventral margins, and particularly by their noncarinate posterior umbonal angulation. The same general characters will also serve to distinguish *P. magnus*, n. sp.

PROTODONAX COALVILLENSIS Vokes, n. sp.
Plate 46, figure 15

Holotype, U.S.N.M. 103731; length (an internal mold of a right valve) 13.5 mm.; height 8.0 mm.; diameter 2.5 mm.

Description.—The valve is moderately small, donaciform, with a relatively high umbone situated approximately at the posterior third of the length. The anterior dorsal margin is relatively straight and gently sloping to the broadly rounded anterior end, in which the greatest convexity of the arc is slightly below the midheight; ventral margin very gently convex but rather sharply angulate to the short, very slightly convex posterior end. The posterior dorsal margin is moderately long and slightly concave. The surface of the valve is unknown, but the posterior angulation, as represented on the internal mold, was rounded, much less sharply angulate than is the case, even in internal molds, of most other species, being similar to *P. atlantis* (Stephenson) in this respect.

The pallial sinus, muscle scars and smooth internal margins are typical of the genus. The holotype shows proportionally elongate posterior laterals, the ventral being markedly stronger than the dorsal. The anterior laterals seem to have been relatively thin and much weaker than the posterior ones. The posterior cardinal was deeply bifid, and the anterior cardinal of the left valve, judging from the nature of the socket for its reception, was trigonal and moderately elongate.

Locality and horizon.—Known only from the type specimen, a small piece of sandstone containing the holotype and three other examples. This was collected from strata immediately beneath the lower coal horizon at Coalville, Utah [zone 1 in the section given by Stanton (1893, p. 38) and probably no. 13 in that given by Wegemann (1915, p. 163)]. Associated faunas indicate a Dakota-Graneros age for the species.

Remarks.—The relatively low, rounded posterior umbonal angulation will distinguish this species from all others of the genus except *P. atlantis* (Stephenson). The present species may be distinguished from that form by its proportionally higher valve, its relatively shorter and broader anterior end, its more anteriorly situated umbones, and by the absence of the subumbonal ridge which is shown in the internal mold of the holotype of Stephenson's species. In both forms the surface angulation has a trend of about 60° to the horizontal, as determined from the length of the valves.

PROTODONAX? CUNEATUS (Stanton)
Plate 46, figure 14

Donax cuneata STANTON, 1893, p. 110, pl. 25, fig. 1; HERRICK and JOHNSON, 1900, p. 40, fig. 1. Not *Donax cuneata* STANTON, 1899, p. 638 [=*Protodonax oblonga* (Stanton)].

The holotype of this species has not been available for study, but the specimen from the third ridge at Coalville, Utah, mentioned in the original description has been examined (U.S.N.M. 103732). It is a natural internal mold in coarse sandstone and is, unfortunately, too poorly preserved to show the

impression of the pallial line or hinge characters. The hinge of the type has been described by Stanton as

> not being exposed sufficiently for figuring, but its structure can be seen fairly well—There are two approximate cardinal teeth under the beak, and both the anterior and posterior lateral teeth are well developed, the former being elongate and located a considerable distance in front of the beak while the latter is shorter and is near the cardinal teeth.

This hinge is quite suggestive of that of *Protodonax*, although, as has been noted, the laterals are paired in the other species in which they have been well observed. However, the dorsal lateral is always much weaker than the ventral, and Stanton may well have failed to note its presence. The presence of the two cardinal teeth, together with the anterior and posterior laterals, considered with the shape of the valve, which while extreme is still quite characteristic, makes it seem quite probable that this species is to be referred to *Protodonax*.

The umbones are unusually posterior in position, being located almost at the posterior sixth of the length of the valve. The posterior umbonal angulation is very sharp, and the surface of the valve posterior to it drops sharply at an angle of almost 90° to the plane of the anterior portion of the valve. The angulation has a trend of 70° to the horizontal. These features will distinguish the present form from all other species of the genus.

Locality and horizon.—Described by Stanton, from strata at Old Bear River City, Wyoming, of which it is said (Stanton, 1893, p. 45) that "the exact position . . . could not be determined on account of faults." Stanton suggests that the species found there "permit its correlation with No. 4 of the Coalville section," a correlation which would suggest an upper Carlile, or possibly a Niobrara age for the species. Also known from the "Third ridge" at Coalville, Utah, associated with a fauna of Niobrara age.

SPECIES FROM THE MONTANA GROUP

PROTODONAX MAYLANDENSIS (Landes)
Plate 46, figures 12, 13

Tellina maylandensis LANDES, 1940, p. 159, pl. 5, figs. 13, 14.

Hypotype, U.S.N.M. 103733; length 8.8 mm.; height 6.3 mm.; diameter (left valve) 1.5 mm.

Hypotype, U.S.N.M. 103733; length 10.7 mm.; height 6.1 mm.; diameter (right valve) 1.7 mm.

This species has been well described by Landes, and the description clearly elucidates all the characters of the present genus. There is, however, considerable variation in the relative length-height proportions exhibited in specimens in the collections of the U. S. National Museum. Hypotype 103733 (pl. 46, fig. 12) is almost three-fourths as high as it is long, whereas the type, as indicated in Landes' description, is but one-half as high as long, a condition rather rare in the large collections available, in which the height is more generally from two-thirds to three-fourths the total length of the valve. Hypotype 103733, illustrated on plate 46, figure 13, is of more average proportions. The trend of the surface angulation, called an umbonal ridge in the original description, varies according to the proportionate height of the individual example, ranging between 50° and 55° from the horizontal. This ridge is quite rounded, recalling that of *P. coalvillensis*, n. sp., and *P. atlantis* (Stephenson), from which species the present form may be separated by its anterior end, in which the greatest convexity is toward the dorsal side of the arc, as in *P. oblongus* (Stanton). The latter species has a muc hsharper posterior umbonal angulation.

Locality and horizon.—Known only from southern Alberta, Canada, in strata designated by Landes as the base of the Foremost formation. The types are from the NE¼ sec. 8, T. 1, R. 9 W. of 4th Meridian, and the species is also said to occur at the mouth of Pakowki Coulee, SE¼ sec. 29, T. 2, R. 8 W. of 4th Meridian. Represented in the collections at U. S. National Museum from strata presumably of same age at localities three-quarters of a mile northwest of Pendant d'Oreille police barracks on hill 100 feet above bed of Milk River; 1 mile north of the barracks; and from the base of the bluffs along Milk River 10 miles below the Pendant d'Oreille police barracks.

PROTODONAX EXAQUILIUS Vokes, n. sp.
Plate 46, figures 20–22, 24

Holotype, U.S.N.M. 103734; length 19.0

mm.; height 8.3 mm.; diameter (internal mold of right valve) 2.5 mm.

Paratype, U.S.N.M. 103738; length 30.4 mm.; height 14.5 mm.; diameter (internal mold of left valve) 4.1 mm.

Paratype, U.S.N.M. 103735; length 20.4 mm.; height 9.8 mm.; diameter (internal mold of left valve) 3.0 mm.

Paratype, U.S.N.M. 103735; length 17.0 mm.; height 6.7 mm.; diameter (internal mold of right valve) 2.5 mm.

Description.—The shell is of moderate size, elongate-donaciform, with moderately prominent umbones situated at the posterior fourth of the length in most specimens. The anterior dorsal margin is slightly concave near the umbones but becomes straight at or slightly behind the midlength of the valve, and rounding anteriorly into the rather broadly arched anterior end, which in turn rounds gently into the straight ventral margin. The posterior margin is relatively short and straight, being sharply angulate below to the ventral margin and above to the slightly concave anterior dorsal edge. The posterior umbonal angulation is sharp and pronounced and has an average trend of 58° to 60° to the horizontal as determined from the length of the valve.

Hinge incompletely known, with an elongate, thin anterior lateral and a moderately short, relatively light posterior lateral in the left valve, and with paired anterior and posterior laterals in the right. Pallial line poorly preserved, but apparently typical of the genus. Adductor scars of usual shape and proportions, not strongly impressed.

Locality and horizon.—Known only from the Virgelle sandstone, the basal formation of the Montana group, in northern Montana. It is represented in collections from the following localities: (a) Top of heavy bed of cross-bedded sandstone in ridge west of St. Mary River, 4 miles northeast of the mouth of Kennedy Creek, Blackfoot Indian Reservation (paratypes 103735); (b) same regional locality as above, but collections made 30 feet lower in the section (holotype); (c) top of ridge south of Lake Creek, about 2 miles east of Basin Mountain and 12 miles west of Browning, Montana, on Blackfoot Indian Reservation; elevation 5650 feet (paratype 103738); (d) southeast side of south fork of Cutbank Creek, at head of gorge in SE¼ sec. 4, T. 32 N., R. 12 W., Montana.

Remarks.—There is a considerable range of variation in the general proportions and in the position of the umbones in this species. The ratio of height to length of the valve averages approximately 1:2.1, but ranges in the collection from 1:2.05 to 1:2.54. In most specimens, the umbone is situated approximately at the posterior fourth of the length, but in one paratype it is approximately at the posterior third, and in one imperfect specimen is even at the posterior sixth; these variations somewhat affect the angle of the posterior umbonal angulation, the degree of the effect depending, however, upon the relative height of the valve.

This species rather closely resembles *P. sphenicus*, n. sp., in its general proportions. They can be distinguished, however, by the somewhat less inflated valves, the less sharply angulate posterior umbonal angulations, the shorter truncate posterior end, and the broader anterior end of the present form.

A rather poorly preserved mold of a right valve (U.S.N.M. 103736) collected in the Virgelle sandstone from a low ridge just northeast of the outlet of Lower St. Mary Lake, Glacier National Park, Montana, represents either an extreme variation of *P. exaquilius*, or, more probably, a new, undescribed species (pl. 46, fig. 19). It is a rather small form, 10.8 mm. long and is relatively very high, having a height:length ratio of almost 1:1.55. The umbones are situated at the posterior fourth of the length, but owing to the extreme height of the valve, the posterior angulation, which is relatively low and somewhat rounded, has a trend of 76°, much greater than that of *P. exaquilius*. The hinge, pallial, and muscle characteristics cannot be observed owing to the poor preservation.

PROTODONAX CHLOROPAGUS
Vokes, n. sp.
Plate 46, figure 11

Holotype, U.S.N.M. 103737; length 18.6 mm.; height 11.0 mm.; diameter (right valve) 4.0 mm.

Description.—This species is based upon a single right valve on which the shell material is preserved over a portion of the sur-

face, and broken away over the rest. The valve is of average size, donaciform and relatively high, with the moderately inflated umbone situated approximately at the posterior sixth of the length of the valve. The anterior dorsal margin is long, very slightly concave, almost straight, the anterior end is rounded, the ventral margin broadly convex, sharply angulate posteriorly to the rather long, apparently somewhat concave posterior end. The posterior dorsal margin is short and convex. The surface of the valve is smooth, ornamented only by fine lines of growth. The posterior umbonal angulation was rather sharp and steep, trending at an angle of 74°; and the posterior area of the valve surface, in response to the extremely posterior position of the umbone, dropped abruptly to the valve margin at an angle of 72° to the plane of the anterior portion of the valve.

The matrix in which the specimen is preserved is too refractory to permit an adequate development of the hinge structure. Enough can be seen, however, to indicate the presence of the characteristic anterior laterals, and apparently also of unusually short posterior laterals. A relatively long, subtrigonal cardinal tooth is also present and is seemingly the posterior cardinal. The nymph plate is rather deeply excavated and quite long in comparison with the short posterior dorsal margin. Muscle scars and pallial line not visible.

Locality and horizon: The holotype was collected from the Mesaverde formation in the Rock River region of Wyoming, from the SW¼ sec. 22, T. 21 N., R. 77 W. According to John B. Reeside, Jr. (personal communication), this should be rather high in the Mesaverde formation.

Remarks.—This species is very similar to *P.? cuneatus* (Stanton), both having umbones located extremely posteriorly and relatively high. They differ, however, in the relatively shorter and broader anterior portion of the valve of *P. chloropagus;* in the slightly lesser slope of the posterior surface of the valve in the present species, resulting from the fact that there is a distinct posterior prolongation of the valve giving definite posterior and posterior-dorsal margins, whereas the two margins have been so merged in *P.? cuneatus* as to give a posterior margin that extends in a line from the posterior ventral end to the umbone without the delimitation into posterior and posterior-dorsal areas.

SPECIES FROM THE ATLANTIC COASTAL FAUNA

PROTODONAX ATLANTIS (Stephenson)

Plate 46, figure 23

Donax? atlantis Stephenson, 1936, p. 381, pl. 3, figs. 1–3.

Holotype, M.C.Z. 15114; length 30.0 mm.; height 16.6 mm.; diameter (of squeeze of holotype, an external mold) 4.5 mm.

Paratypes, M.C.Z. 15115; incomplete molds showing right hinge, and left interior.

This species, which has been well described and figured by Stephenson is a typical *Protodonax* in every respect. The most characteristic features of the species are the relatively high, broad umbones, the low, broadly rounded posterior umbonal "angulation," and the somewhat narrowed anterior end of the valve. The umbone is situated just anterior to the posterior fourth of the length of the valve.

The type was not available for examination, and a cast of this specimen was not adequate to show the "very fine, faint, radiating lines" which "can be detected in places." It may be that, as in *P. stantoni*, there are subsurficial features visible only on areas where the shell material has been slightly eroded.

Internally, the species exhibits the characteristic pallial line, muscle scars and smooth inner margin. A partial hinge of a right valve is unusual in that the ventral anterior lateral, which as usual is stronger than the dorsal one, extends in normal strength to a point immediately posterior to the anterior adductor, where it seems to be sharply reduced in strength, but to be prolonged as a curving ridge forming a dorsal boundary to the anterior muscle scar. About midway along the length of this portion of the "tooth" it becomes fused, for a short distance, with the dorsal lateral, but separates again to terminate in normal position immediately below the anterior end of the latter tooth. No left hinge has been available, but it would seem that the anterior lateral of that valve must be shorter than normal and be terminated anteriorly by the

posterior end of the adductor.

The posterior cardinal tooth of the right hinge is of normal shape but may have been slightly bifid. The anterior cardinal structure cannot be distinguished. The anterior cardinal of the left valve, however, seems from the nature of the corresponding socket in the right to have been heavy, very broadly trigonal and, probably, to have been confluent anteriorly with the posterior end of the anterior lateral, a condition well shown in the left hinge of *P. minutissimus* (Whitfield). The posterior left cardinal seems to have been of normal proportions.

Locality and horizon.—Known only from material dredged from Georges Bank in the western Atlantic Ocean, Latitude N. 42° 24′ 30″, Longitude W. 68° 07′ 30″, from depths of 480 to 596 meters. The fauna obtained from the rocks recovered in the dredge indicates an upper Campanian or possibly lower Maestrichtian age, in terms of the European time section, for this species.

SPECIES FROM THE CRETACEOUS (APTIAN) OF LEBANON

PROTODONAX MINUTISSIMUS
(Whitfield)
Plate 46, figures 16–18

Donax minutissimus WHITFIELD, 1891, pp. 386, 411, pl. 7, figs. 12, 13.
Donax? minutissimus WHITEFIELD, BLANCKENHORN, 1934, p. 257.

Holotype, A.M.N.H. 16400/1; length 5.2 mm.; height 4.0 mm.; diameter (both valves) 2.5 mm.

Topotype, A.M.N.H. 25988: 1; length 12.3 mm.; height 8.2 mm.; diameter (left valve) 3.1 mm.

Topotype, A.M.N.H. 25988: 2; length 16.4 mm.; height 11.9 mm.; diameter (left valve) 5.0 mm.

The holotype, the only specimen available to Whitfield, is obviously an immature representative. Two additional left valves were obtained by the writer while studying the stratigraphy and Cretaceous faunas of the Lebanon Mountains during the tenure of a fellowship of the John Simon Guggenheim Memorial Foundation. These are topotypes and have been compared with Whitfield's type specimen; they show that the species attains a relatively normal size for representatives of the genus.

The surface of these two specimens, though imperfectly preserved, shows no suggestion of radial striation, and a careful microscopic examination of the holotype fails to reveal the basis for Whitfield's statement, in his original description, that the "surface [is] apparently finely striated." Surface ornamentation consists only of lines of growth, which become moderately prominent toward the ventral margin. The most conspicuous surface feature is the prominent angulation extending from the posterior side of the umbone to the sharply angulate posterior ventral margin. In the larger topotype the angulation is sharper than that of the smaller specimen and rises above the level of the valve to form a distinct carina. In this species it has a trend of approximately 70° to 72° from the horizontal as determined from the length of the valve.

A well-preserved left hinge is unusual only in the fact that the anterior cardinal is very broadly trigonal and is confluent anteriorly with the posterior end of the elongate anterior lateral tooth. The posterior cardinal is fused to the anterior end of the nymph plate at its posterior dorsal side, not throughout as in the genotype. The pallial line is very imperfectly preserved but seems to have been entirely typical. The adductor scars are not as deeply impressed as normal, but were of the characteristic shape and proportions.

In its outline this species is reminiscent of *P. atlantis* (Stephenson) but may be distinguished by its relatively greater height, with higher, narrower, and more prominent umbones, and its proportionally narrower and more sharply rounded anterior end. This anterior narrowing of the valve results from a somewhat steeper anterior dorsal slope and a more arcuate ventral margin. The surface angulation is much more strongly developed on the present form than on the Atlantic one.

Immature specimens of *P. oblongus* (Stanton) also have a somewhat similar outline but may be distinguished by the lesser obliquity of the surface angulation, and by their more anteriorly situated umbones (at the posterior third of the length in immature *P. oblongus*, and the posterior fourth in *P. minutissimus*). The umbones are somewhat more prominent in the Leba-

non species, and the anterior end narrower. *P. sphenicus*, n. sp., has a somewhat similarly narrowed anterior end, but the valves are much longer in proportion to the height, the umbones are more anterior, and the valves more strongly inflated.

Locality and horizon.—Known only from the "Olive Locality" at Abeih, in the Lebanon Mountains, Republic of Lebanon. The associated fauna indicates an Aptian age for this species, the only Lower Cretaceous representative of the genus as yet known.

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CORALS FROM THE POST-OSAGE MISSISSIPPIAN OF MONTANA

LAURENCE L. SLOSS
Montana School of Mines, Butte

RECENT paleontologic literature (Jeffords, 1943; Kelly, 1942; Merriam, 1942) gives evidence of a renewed interest in the Mississippian coral fauna of the Rocky Mountains and adjacent areas in western North America. This paper is a minor addition to what, it is hoped, will become a greatly expanded knowledge of these faunas. It is the writer's belief that coral studies will prove to be the keys to the unravelling of problems of classification and correlation in the thick Mississippian limestones of the Cordilleran geosyncline and the foreland area to the east.

The corals discussed in this paper are from two stratigraphic horizons and, chiefly, from two localities:

1. Yakinikak limestone: sec. 27, T. 37 N., R. 23 W., Flathead County, Montana. On Yakinikak Creek road, approximately 4 miles west of the North Fork of Flathead River.

2. Amsden formation: SW¼ sec. 25, T. 1 N., R. 2 W., Jefferson County, Montana. Along Northern Pacific tracks and north bank of Jefferson River, approximately two miles northwest of Sappington station.

The name Yakinikak was applied by Willis (1902, pp. 316, 324) to an isolated block of limestone which extends from Yakinikak Creek to the British Columbia border along the west side of the valley of the North Fork of Flathead River in northwestern Montana. Willis believed that the limestone rests conformably on an unnamed quartzite; the present writer is of the opinion that the limestone represents a remnant of an imbricate thrust sheet that has been thrust over the subjacent quartzite. The latter is very possibly correlative with the Pennsylvanian Rocky Mountain quartzite. The Yakinikak must be correlative with parts of the Rundle and Hannan limestones of the Rocky Mountain front but probably represents a much more westerly facies than is indicated by its present position.

Weller (in Willis. 1902) identified the fauna of the Yakinikak as St. Louis in age. Blackstone (1934) identified 12 brachiopod species in the Yakinikak, nine being Meramec and three Kinderhook or Osage in age. Brachiopods associated with the coral fauna are these:

Punctospirifer transversa (McChesney)
Reticulariina spinosa (Norwood and Pratten)?
Composita trinuclea (Hall)
Camarotoechia mutata (Hall)
Dielasmella compressa Weller
Girtyella indianensis (Girty)
Cliothyridina sp.

The most prominent Yakinikak corals are *Caninia cornucopiae* Michelin and *Lithostrotion* cf. *L. irregulare* (Phillips). *Caninia cornucopiae* occurs in the upper Tournaisian and lower Viséan of Belgium and the British Isles, reaching maximum development in the C_1 subzone (Salée, 1910). Vaughan (in Dixon and Vaughan, 1911, p. 555) has described a closely related form from the uppermost Viséan (D_3) of England. *Lithostrotion* is confined to the Viséan of England (Smith 1920, p. 51) with *L. irregulare* occurring most abundantly in the upper Viséan. The coral herein described as *Tryplophyllites* cf. *T. enniskilleni* is probably of only slight correlational value, but it may be noted that *T. enniskilleni* is confined to the Viséan of England and Belgium. Thus it would appear that the Yakinikak coral fauna is Viséan in age on the western European time scale and, since the *Caninia* is the most positive identification of the three, it carries more weight, suggesting lower Viséan. Such statments should not be taken too literally, however, until much more is known of the stratigraphic ranges of American Carboniferous corals.

Correlation of the Yakinikak and part of the Lake Valley limestone of New Mexico is suggested by the presence in the latter formation of a coral strongly resembling *Caninia cornucopiae* (Jeffords, 1943). Laudon and Bowsher (1941, p. 2132), however, have

shown the Lake Valley limestone to be of Osage age.

The problems involving the Amsden formation have been discussed recently by Perry and Sloss (1943, pp. 1293–1294) and need not be repeated here. Brachiopods associated with the Amsden coral near Sappington include the following:

Spirifer increbescens Hall
Spirifer pellaensis Weller
Spirifer welleri Branson
Linoproductus ovatus (Hall)
Gigantella brazeriana (Girty)
Composita subquadrata (Hall)

The occurrence of *Caninia juddi* (Thomson) in the lower half of the Amsden formation serves to emphasize the Chester age of that part of the formation. The species is also found in the Chester-age upper Windsor formation of Nova Scotia, and corals of the same type occur in the Golconda formation of Tennessee (Easton, 1943, p. 277). In the British Isles and Belgium, *C. juddi* is confined to the uppermost Viséan (upper *Dibunophyllum* zone).

Genus Caninia Michelin

The genus has been discussed at length by Carruthers (1908, pp. 158–171) and Salée (1910, pp. 1–62). Since modification by Lewis (1929, pp. 158–171) the genus and its application to European Lower Carboniferous corals has been well established. In North America, however, the genus has been all but ignored, as pointed out by Jeffords (1943, pp. 545–548), who has presented an excellent statement of the nomenclatorial confusion involving *Caninia* and the American usage of *Campophyllum*. Further clarification of this problem has been presented by Easton (1944a).

Caninia cornucopiae Michelin
Plate 48, figures 5–9

The species has been thoroughly described by Salée (1910) and Carruthers (1908, p. 159). The following brief description will serve to point out features peculiar to the Montana specimens.

External characters.—Corallum cylindrical. Maximum observed diameter, 24 mm., average 15 mm. Maximum observed height in broken fragments 60 mm.; height of complete specimens probably considerably greater. Epitheca marked with fine closely spaced growth lines, barely perceptible septal grooves.

The corals occur closely packed in the matrix, suggesting a compound growth, but no evidence of lateral gemmation or colony form is apparent.

Transverse section.—Ephebic sections at a diameter of 20 mm. exhibit 30 major septa, attenuated and reaching one-half to two-thirds the distance to axis. Minor septa are short spines confined to the peripheral border of dissepimentarium unless epitheca is repeated in dissepimentarium by rejuvenescence. Dissepimentarium narrow, composed of one to three rows of irregular concentric and herringbone dissepiments. Cardinal fossula open and inconspicuous. Neanic sections (6 mm.) usually exhibit 18–20 short amplexoid septa, no minor septa or dissepiments. Rare neanic sections have long septa extending nearly to axis.

Longitudinal section.—Tabulae commonly complete or nearly complete, flat except where turned abruptly down at borders of tabularium and at fossula, spaced 0.5 to 1.0 mm. apart. Dissepiments elongate and irregular. Septa reach greatest length just above tabulae.

Discussion.—With two points of exception the Montana specimens agree almost perfectly with descriptions and figures of the morphology and ontogeny of British and Belgian examples of *Caninia cornucopiae* Michelin. The "*vermicularis*" and "*dumonti*" growth stages of Carruthers (1908, p. 161), with long septa and a zaphrentoid fossula are not well represented in the Montana specimens, the earliest stage commonly observed being Carruthers' "*nystiana*" phase. The early stages may be lost in lower portions of the coralla not preserved in the Montana specimens, or they may be missing through tachygenesis. The Montana specimens bear fewer septa at an equivalent diameter than most of the British and Belgian forms (28–30 at 20 mm. compared with 33). Considering the distance from the type locality of the species the writer is much more impressed with the evident points of agreement between the Montana and the British or Belgian forms than with relatively minor points of difference in what has been shown to be a highly variable species.

Recently Jeffords (1943) has described a new species, *Caninia arcuata*, from the Lake Valley limestone of New Mexico. It is the opinion of this writer that the Lake Valley coral is also conspecific with *C. cornucopiae*. Jeffords states that *C. arcuata* "differs [from *C. cornucopiae*] in its larger size, shorter septa of the early parts of the corallite, and downbending of the tabulae around the fossula." However, the maximum diameter (28.2 mm.) given for *C. arcuata* is well within the range of diameters of *C. cornucopiae;* the British and Belgian species commonly passes through an amplexoid neanic stage (Carruthers' "*nystiana* phase"), and is characterized by depression of the tabulae at the cardinal fossula (Carruthers 1908, p. 164). In view of the apparent strong influence of environment on the inherent variability of corals and the present confusion of interpretations of the species concept as applied to corals, it would appear to be in the interest of taxonomic simplicity to refer both the Montana and New Mexico corals to *Caninia cornucopiae*. There is nothing in their basic morphologic and ontogenetic characters which would make such a reference incompatible with sound taxonomic practice. When, as is inevitable, a more complete study of western North American Mississippian corals has been made, it will be possible to re-evaluate these two forms in terms of the variants which will come to light in other areas, and the synonomy with *C. cornucopiae* can be established or refuted on a firmer basis than is possible at present.

Locality.—Yakinikak limestone, sec. 27, T. 37 N., R. 23 W., Flathead County, Montana.

CANINIA JUDDI (Thomson)
Plate 48, figures 1–4

The description of the species given by Lewis (1924, pp. 391–397) for specimens from the upper *Dibunophyllum* zone of England fits the corals from the Amsden formation so perfectly that very little further description is necessary here. In shape (ceratoid to cylindrical), height (up to 150 mm.), diameter (maximum 78 mm., average 40–65 mm.), number of ephebic major septa (50–54), details of septa, dissepiments, and tabulae, and in ontogeny, the English and Montana specimens are almost identical. The Montana forms tend to be more conical in shape, slightly greater in maximum diameter, and to have slightly shorter ephebic septa than the English examples. All of these characters, however, have been demonstrated to vary widely under environmental control, and the differences noted do not seem sufficient to justify so much as a new variety.

Certain Amsden specimens exhibit retarded neanic characters, such as long, considerably thickened septa and the absence of dissepiments at a diameter which is usually marked by ephebic characters in normal specimens. These atypical individuals might easily be mistaken for a separate species, particularly when the ephebic portion of the corallum is not preserved, as is often the case. However, whenever the upper portions of the atypical forms are found it may be shown that they eventually attain ephebic characters. Similar variations occur among the English forms. Conversely, some small Amsden specimens exhibit an accelerated ontogeny with amplexoid septa and well-developed dissepiments at a diameter of only 17 mm. These specimens closely approximate *Caninia minor* Lewis (1930, p. 267) from the *Dibunophyllum* zone of the Isle of Man, but until it can be shown that continued growth of these forms does not bring about a reversion to normal ontogenetic stages the writer prefers to include them in *C. juddi*. Other confusing specimens are those from which the rather fragile dissepimentarium has been removed, making the wall of the tabularium ("theca" of some authors) appear to be the epitheca.

Longitudinal sections of a few Amsden specimens show the closely packed, flat tabulae typical of *C. juddi cambrensis* Lewis, and it is possible that the variety is represented in the Amsden fauna. However, the tabulae of other specimens may be both flat and closely spaced or arched and more widely spaced at different heights in the corallum.

Caninia juddi has been previously reported in North America from the upper Windsor formation of Nova Scotia (Lewis, 1935, p. 129). The Montana specimens in their more regular growth agree more closely with the English forms than with the variety *dawsoni* from the Windsor, which is charac-

terized by numerous restrictions and geniculations.

Locality.—Lower half of the Amsden formation, SW¼ sec. 25, T. 1 N., R. 2 W., Jefferson County, Montana.

Badly crushed fragments of the ephebic portions of corals referable to the species were observed in float boulders from the Amsden formation on Haymaker Creek, south flank of the Little Belt mountains, sec. 1, T. 10 N., R. 12 E., Wheatland County, Montana. Poorly preserved specimens were also obtained from the Amsden at Sheep Creek Canyon, "Blacktail" Range, sec. 7, T. 9 S., R. 8 W., and sec. 13, T. 9 S., R. 9 W Beaverhead County, Montana; and on the Nigger Hollow road, SW¼ sec. 2, T. 2 N., R. 2 W., Jefferson County, Montana.

Genus LITHOSTROTION Fleming

Lang and Smith (1935, p. 551) have presented a revised diagnosis of the genus, and recently Kelly (1943) and Merriam (1943) discussed the genus with reference to North American forms. The latter writers agree substantially with Hayasaka (1936) that many American forms referred to *Lithostrotion* exhibit a peripheral border of lonsdaleoid dissepiments and should be included in *Lithostrotionella* Yabe and Hayasaka. Smith (1920, p. 53) concurs in excluding previously described American species from *Lithostrotion*. Merriam's (1942, p. 377) species, *Lithostrotion* (*Lithostrotion*) *packardi*, from the Coffee Creek formation, Lower Carboniferous, of central Oregon, appears to fit *Lithostrotion* sensu stricto in that the species exhibits a septal columella and does not have persistent lonsdaleoid dissepiments. The same is apparently true of *Lithostrotion harmodites* figured and briefly described from western Kentucky by Ulrich (1905, p. 46, plate 5, figure 14). The writer believes that the Montana form described below also has the necessary qualifications for admission to the small but select group of American corals referable to *Lithostrotion*, sensu stricto.

LITHOSTROTION cf. L. IRREGULARE (Phillips)
Plate 48, figures 11–16

External characters.—Compound phaceloid coralla, some corallites touching, others spaced up to 8 mm. apart. Corallites cylindrical, flexuous. Diameters average 5.5 mm. Calyx and epitheca unknown.

Transverse section.—Twenty to 24 thin major septa extend to, or closely approach, columella. Minor septa short (¼ mm.) extend less than one-fourth distance to axis. Dissepimentarium composed of single row of concentric dissepiments. Tabulae truncated in plane of section appear as numerous concentric structures in tabularium. Elongate columella formed by dilation of axial end of one (counter?) protoseptum or two opposing (counter and cardinal?) protosepta. Septal extensions appear on columella in some sections as short spines forming "centipede cross section" described by Lewis (1930, p. 274). No cardinal fossula apparent.

Longitudinal section.—Columella apparently continuous but may not appear so in all sections because of flexure of corallite. Thickness of columella varies with orientation with respect to plane of section. Tabulae characteristically incomplete but occasionally complete, commonly flat or bent down near periphery, flat across axis, more steeply inclined between axis and periphery. Tabulae do not form part of columellar structure. Single vertical row of globular dissepiments forms narrow dissepimentarium.

EXPLANATION OF PLATE 48

FIGS. *1–4—Caninia juddi* (Thomson). Amsden formation near Sappington, Montana. *1*, Transverse section, ephebic stage, ×1. *2*, Transverse section, early ephebic stage, ×1. *3*, Transverse section, neanic stage, ×1. *4*, Longitudinal section, ×1. (p. 311)

5–9—Caninia cornucopiae Michelin. Yakinikak limestone, Yakinakak Creek, Montana. *5*, Transverse section, gerontic stage, ×2. *6*, Transverse section, ephebic stage, ×2. *7*, Transverse section neanic stage, ×2. *8*, Longitudinal section, ×2. *9*, Longitudinal section, ×1. (p. 310)

10—Triplophyllites cf. *T. enniskilleni* Milne-Edwards and Haime. Yakinikak limestone, Yakinikak Creek, Montana. Calicular view of weathered specimen, ×2. (p. 313)

11–16—Lithostrotion cf. *L. irregulare* (Phillips). Yakinikak limestone, Yakinikak Creek, Montana. *11–13*, Transverse sections, ×2. *15–16*, Longitudinal sections, ×2. (p. 312)

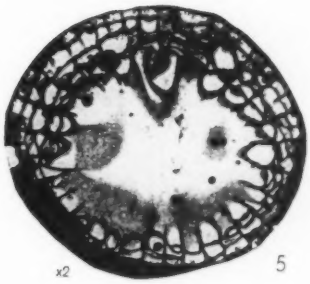
x1 1

x1 2

x1 3

x1 4

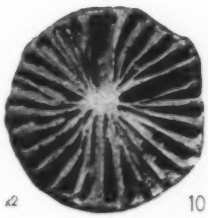
x2 6


x2 5

x2 7

x2 8

x1 9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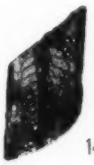
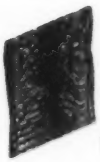
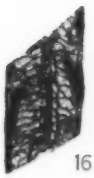
x2 11

x2 12

x2 13


x2 14


x2 15


x2 16

Sloss, Mississippian Corals

Discussion.—This is quite possibly a new species, but the preservation of the specimens available is not sufficiently good to make possible an adequate study and description of some morphologic details. Therefore the coral has been tentatively assigned to the established species it most closely resembles. In a classification of British Lithostrotiontidae Smith (1920) lists the dimensions of several species, among which the figures given for *L. irregulare* are closest to the dimensions of the Montana form. *L. irregulare* is described by Vaughan (1905, p. 279) as having no more than a single row of dissepiments—apparently an unique feature among *Lithostrotion* of comparable size. Vaughan further states that the species is characterized by clisiophylloid structures formed by upturned tabulae near the axis, a development similar to that seen in a few transverse sections of the Montana form. Corals referred to *L.* (*Siphonodendron*) *irregulare* by Yu (1933, p. 93) also appear to closely resemble the specimens herein described, differing chiefly in shorter major septa and a less well defined columella. Superficially the Montana form approaches *L. martini* (Milne-Edwards and Haime) and *L. stansvellense* Smith in number of septa and colony form, but differ in having a single row of dissepiments as compared to several rows in those species.

Locality.—Yakinikak limestone, sec. 27, T. 37 N., R. 23 W., Flathead County, Montana.

Genus TRIPLOPHYLLITES Easton

The taxonomic status of zaphrentoid corals has been discussed by O'Connell (1914), Lewis (1930, p. 12), Schindewolf (1938, pp. 439–445), Stewart (1938, pp. 18–19), Sanford (1939, pp. 406–408), and Lang, Smith, and Thomas (1940, p. 141). Recently, Easton (1944b, pp. 35–38) has proposed the new genus *Triplophyllites* to cover many species formerly included in *Zaphrentis*, *Triplophyllum*, *Menophyllum*, and *Zaphrentoides*. In view of the current taxonomic confusion involving the family Hapsiphyllidae and the widespread application of *Zaphrentis* (or *Zaphrenthis*) to Carboniferous species quite unrelated to the Devonian genolectotype, *Z. phrygia*, Easton's move toward simplification should prove acceptable to many workers who have been forced to cling to *Zaphrentis* as a form genus or become involved with a series of minutely differentiated genera and subgenera of no stratigraphic significance. Still further simplification would be welcomed by many stratigraphers.

TRIPLOPHYLLITES cf. T. ENNISKILLENI (Milne-Edwards and Haime)
Plate 48, figure 10

External characters.—Corallum simple, curved ceratoid. Maximum dimensions of fragmental coralla: height, 25 mm., diameter, 14 mm. Complete calyx unknown; eroded specimens exhibit deep, narrow cardinal fossula on concave side of corallum; weakly developed alar fossulae may or may not be developed. Epitheca thin, unornamented, commonly decorticated.

Transverse section.—Approximately 30 thickened major septa present in ephebic stage. No minor septa. Most septa, except cardinal and alar, extend to axis, coalescing to form a solid axial mass. Cardinal fossula prominent, formed by abortion of cardinal septum; fossular shape variable but commonly with equal width at periphery and axis, slightly constricted near center. Some, but not all, specimens exhibit alar fossulae formed by partial or nearly complete reduction of alar septa. No dissepiments.

Longitudinal section.—Details obscured by thick septa. Tabulae irregularly spaced, nearly complete, flat or slightly domed in center, inclined downward at periphery. Sections cut in plane of cardinal septum show tabulae which rise gently from counter side to axis, very steeply depressed on cardinal side of axis to form floor of deep fossula.

Discussion.—This, too, is probably a new species, but until more complete and better-preserved specimens are found it is referred to the most closely related described species. The Montana form is smaller than *Triplophyllites enniskilleni* but has the same number of septa at a comparable diameter. It closely resembles the British species in character of septa and tabulae, and in position, structure and shape of the fossulae. It differs from related species, such as *T. omaluisi* (Milne-Edwards and Haime) and *T. phillipsi* (Milne-Edwards and Haime) in

the position of the cardinal fossula with reference to acceleration of the corallum, and in abortion of the cardinal septum.

T. enniskilleni has been reported on this continent from the upper Windsor formation of Nova Scotia (Lewis, 1935). The Windsor variety is bigger than the Montana form and has a thicker, more ornamented epitheca.

Locality.—Yakinikak limestone, sec. 27, T. 37 N., R. 23 W., Flathead County, Montana.

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JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, PP. 315–318, 2 TEXT FIGS., MAY 1945

A NEOGENE STICKLEBACK FROM THE RIDGE FORMATION OF CALIFORNIA

LORE ROSE DAVID
California Institute of Technology, Pasadena, Calif.

ABSTRACT—*Pungitius haynesi*, a Neogene stickleback from the Ridge formation of southern California is described.

A SPECIMEN of the piscine genus *Pungitius* Costa was found in dark-gray shale of the Ridge formation near Piru Creek, Ventura County, California. This little fish is the first identifiable macrofossil from the Ridge formation, which may be Pliocene or upper Miocene in age. Thus, far, the sparsity or absence of fossil material in these deposits has prevented an age assignment on the basis of direct paleontological evidence.

The fossil fish was collected by E. B. Haynes of Fillmore, California, and generously given to the California Institute of Technology, Pasadena. There are indications that more material of the same species is available at the fossil locality. However, because of present restrictions due to the war, it is not possible to obtain additional specimens, and the type is therefore the only fish now available for description.

Thanks are due Dr. Chester Stock for his interest and assistance in the present paleoichthyological study.

LOCATION AND AGE OF SPECIMEN

The fossil was collected in a dark-gray silty shale exposed in an embankment at the south approach to the first bridge across Piru Creek, going north on the new Ridge Route (U. S. Highway 99) in Los Angeles County. The fish locality (Calif. Inst. Tech. Vert. Pale. Loc. 389) is situated in NW corner, sec. 13, T. 6 N., R. 18 W., U.S.G.S. Tejon quadrangle, California. The strata containing the specimen form part of the Ridge formation. These deposits were briefly mentioned by Clements (1937, p. 218). A more detailed account of the Ridge basin and its sediments was given by Eaton (1939). These shales fall into Eaton's Division II, a thick series of deposits probably of brackish-water and lacustrine origin, and tentatively referred by him to the Pliocene. The comparatively thin unit of a few hundred feet of dark-gray shale in which the fish was found is conspicuous but has been observed only locally, where it crosses the Ridge Route near the base of the Piru Creek bridge. When the new road was constructed in this region, several fossil palm fronds were uncovered. One of these specimens is now in the collections of the California Institution of Technology, but it has not been identified.

DESCRIPTION OF MATERIAL

PUNGITIUS HAYNESI David, n. sp.

Figure 1

Type specimen.—No. 10347, Calif. Inst. Tech. Coll. Vert. Pale. The specimen measures 50.5 mm. in length, including the urostyle, which is broken off; the caudal fin is missing.

Type locality.—No. 389 California Institute of Technology Vert. Pale. Loc.

Description.—An elongate species with slender head, small eye; body behind insertion of second dorsal and anal fins narrows rapidly to caudal peduncle with almost straight margins; caudal peduncle narrow, constricted as in genus. Urostyle broken off, as well as last vertebra. Caudal fin missing.

Outline of body as a whole well preserved, showing typical and evidently undisturbed proportions of body. Only middle of body seems to be slightly distorted in its upper part by intrusion of coarser material into an otherwise fine matrix; this caused loss of middle part of first dorsal and may have slightly lengthened body in this region.

The structures of skull and mouth, opercular region, pectoral and pelvic arches are as in the genus, in so far as they can be observed. Mouth comparatively long for genus, almost closed, turned diagonally forward and upward, teeth faintly preserved

only on premaxilla, ascending process of premaxilla of moderate length, reaching anterior end of orbit. Outlines of fairly large lacrimal and suborbitals visible, the latter partly covering angular preopercular. Triangular opercular ornamented with numerous transverse radii as in genus. Pectoral girdle (see Starks, 1903) with high slender clavicle, hypocoracoid with large ovoid foramen and broad hypocoracoid, extending into slender vertically projected "interclavicle." Interclavicle is met and superimposed posteriorly by pelvic plates. Pelvic girdle strongly forked, the robust upper fork extending near vertebral spine.

Head 3.4 in body, depth of body almost 5, snout a little longer than eye, 4 in head; mouth comparatively long, 3 in head. 15 +19 =34 vertebrae. D 1 =IX?, D 2 =I, 10; spine of second dorsal 3.3 in length of head. First dorsal uncertain as its middle portion is disturbed, however most of its interneurals well formed. Two strong interneurals connected with first two vertebrae, preceding dorsal spines. Following four vertebrae with strong triangular interneurals evidently supporting dorsal shields and spines, third spine partly preserved. Interneurals of following three vertebrae lost, but spine of third of these partly preserved (evidently seventh spine). Tenth vertebra without interneural and spine, same probably true for twelfth and fourteenth vertebrae; eleventh, thirteenth and fifteenth vertebrae support interneurals and evidently spines; strong spine supported by fifteenth vertebra partly preserved forming spine of second dorsal. Interneurals, supported by first 15 vertebrae, of more or less the same strength and not greatly increasing in length as in highly arched species of the genus. Second dorsal inserted at a distance 1.4 times farther from end of snout than from end of body. Anal fin I, 8, inserted slightly behind second dorsal. Pelvic spines missing. About 12 or more pectoral rays, their tips broken off. Except for shields connected with spines of first dorsal and with pectoral and pelvic girdles as described above, no dermal shields are present; if a dermal skeleton was present at all, it evidently was feeble.

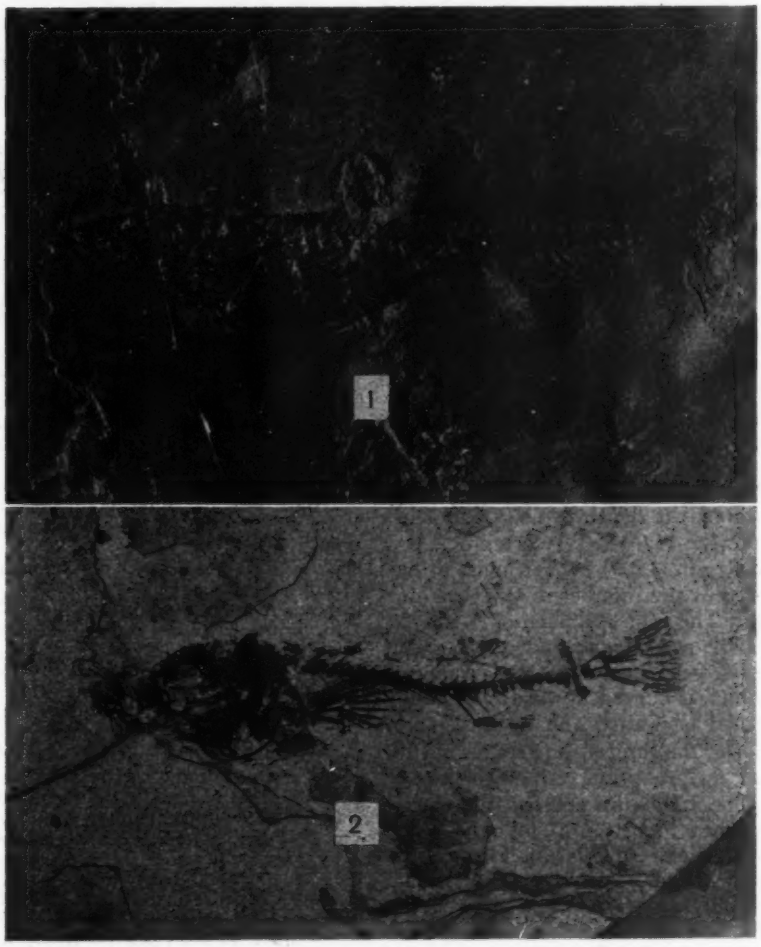
RELATIONSHIPS AND GEOLOGICAL AGE OF FOSSIL

The fossil species seems to be related to the small or nine-spined stickleback. The structure of the head and body as well as the number of vertebrae agree. Although most of the dorsal spines are missing, the structure of the interneurals indicates that there were about 9 spines in the first dorsal, and the skeletal elements of this part of the body agree well with those found in *Pungitius pungitius*. Two specimens of *P. pungitius* from Lake Nipigon, Ontario were used for comparison. Dr. Carl L. Hubbs very kindly donated this Recent material.

These show 15 +19 or 20 =34 or 35 vertebrae, the first specimen thus agreeing with the fossil. The number of soft dorsal and anal rays also falls within the variation of the species. The fossil species evidently differs in possessing a body slightly longer than is normal for *P. pungitius*, and in the farther posterior insertion of the second dorsal fin. Otherwise, the fossil species appears to agree with the very variable living form.

Sticklebacks are restricted to the northern hemisphere and are distributed over Europe from the Arctic Ocean, including Iceland and Greenland, to the Black sea. In Asia they occur in northern Siberia to Transcaucasia, from the Amur to Behring Island to Japan. In America they range from Alaska to California and from Nova Scotia to Cape Cod. Except for a few local species, the sticklebacks are represented in almost their entire region of distribution by two species. *Gasterosteus aculeatus*, the common stickleback, and the nine-spined stickleback, *Pungitius pungitius*. The high-bodied larger, common stickleback with a restricted number of long and strong spines in the first dorsal is easily distinguished from the slender nine-spined *Pungitius*.

Both species occur in salt, brackish, and fresh water and show great variability as exemplified especially in their dermal skeleton. In the northern part of their range in the sea the dermal ossifications are strong, the series of body plates complete, the fin spines usually either long or strong. Toward the southern part of their range in the sea and everywhere in fresh water, the dermal



FIGS. *1*—*Pungitisius haynesi* David, n. sp., Holotype, California Inst. Technology Vert. Paleontology Coll. No. 10347. Ridge formation, upper Miocene or Pliocene, Piru Creek, California. Approximately ×1.8.
2—*Gasterosteus doryssus* (Jordan). Lahontan beds, Pleistocene, near Hazen, Nevada. Collected by D. T. Axelrod. Approximately ×2.

ossification is much weaker. It is interesting to note that the Californian fossil is related to *Pungitius pungitius*, a form not known today in the western portion of North America. The modern species does occur in Europe as well as Asia, and in eastern America from the Arctic south to Long Island. In contrast, *G. aculeatus* is represented by two varieties in California today. Regan (1909), for example, notes *G. aculeatus* (=*G. williamsoni*) in the Santa Clara River and *G. santa-annae* in the Santa Ana River.

P. pungitius is found in America (Schrenkeisen, 1938, Jordan, Evermann, Clark, 1930) in fresh and brackish waters and sometimes in mountain lakes. *Pungitius* is less common today than *Gasterosteus*, but may have had a wider distribution than the latter in late Tertiary times. It is desirable to obtain additional fossil specimens with better-preserved dorsal spines than in the described material in order to verify the rela-

tionship of the Californian form to the living nine-spined stickleback. The fossil fish has a weak dermal skeleton, if any. The occurrence warrants the assumption that the sediment accumulated in fresh water, a view previously accepted with reference to the origin of the strata. Sticklebacks migrate to shallower regions in the spawning season in early summer and retire to deeper pools in ponds toward fall, a habitat in which the fossil may have been preserved.

Only a few fossil sticklebacks are known. *Gasterosteus doryssus* (fig. 2) from the Pleistocene Lahontan beds of Nevada (Hay 1907, 1926; Jordan, 1907) is related to *Gasterosteus aculeatus*. Several specimens of the latter species from Truckee River, Nevada, are in the collection of the California Institute. These show the typical arched outline of *G. aculeatus*, the depth being 3.6 to 4 in body. There are 15+18=33 vertebrae. According to Regan (1909) 29, and more often 31–33 represent the number of vertebrae in *G. aculeatus*. The type specimen of *G. doryssus* (Hay 1907, p. 272) is extended by fossilization, as is well shown by the vertebral column, which is curved upward. The head also is turned backward and upward. One or the other of the three strong spines of the first dorsal fin are preserved in the fossil material. The Lahontan species, therefore, is not related to *P. haynesi*. The only other known fossil sticklebacks are a Pleistocene form from Canada, related to *Gasterosteus aculeatus* (Dawson, 1894), and a neogene type from Siberia (Schtylko, 1934). The wide distribution of the living species of sticklebacks over the northern hemisphere appears to indicate that they have been in existence for some time. The principal species of the Gasterosteidae may have been established by Miocene time. *Pungitius haynesi* is the only fossil stickleback known from California. It is not possible at present to determine definitely the geologic age of the specimen. However, since it is closely related to the living species, it is not likely to be older than middle Miocene; its presence in the Pliocene seems more likely. *P. haynesi* probably became extinct in California at a later time, perhaps as a result of climatic change.

CONCLUSIONS

The small stickleback found in the Ridge formation, near Piru Creek, represents a near relative of living forms. It is probably related to *P. pungitius* (Linnaeus), an inhabitant of Eurasia and the coast of eastern America. The type is not likely to be as old as middle Miocene, and evidently represents a fresh-water variety.

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JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, P. 319, MAY 1945

PALEONTOLOGICAL NOTES

NEW NAMES FOR TWO HOMONYMS

KENNETH E. CASTER
University of Cincinnati, Cincinnati, Ohio

PLEUROTOMA CABINAE Caster, n. name

Dr. Katherine V. W. Palmer has recently called my attention to the name *Pleurotoma* (*Bela*) *rebeccae* by Harris (1895) *versus* Caster (1938). For my 1938 homonym the new name *Pleurotoma cabinae* is now proposed. *P. cabinae* is one of the characteristic fossils of the Lucolo River Eocene (Quimbriz formation) in Portuguese West Africa (Angola). The new name is given in honor of the depository of the type material of my Angola study, the Paleontological Research Institution, whose colloquial name among the founding group was "Cabina."

Genus MCLEARNITES Caster, n. name

My attention has recently been directed to the prior usage of the name *Mclearnia* by Crickmay (1930) for a mollusk *versus* mine for a brachiopod in 1939. For the Caster homonym of 1939 the new name *Mclearnites* is here proposed.

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NEW NAME FOR A COLOMBIAN TERTIARY PLANT

E. W. BERRY
Baltimore, Maryland

In a recently published Johns Hopkins University Studies in Geology (no. 14, p. 179, 1945) I described a new species of the papilionaceous genus *Triptolemaea* from the late Tertiary of eastern Colombia as *T. tertiaria*. This name is antedated by *T. tertiaria* Berry, 1935, Am. Philos. Soc., vol. 75, p. 578, from the Pliocene of eastern Brazil and should therefore be rechristened. The Colombian form may appropriately be called *Triptolemaea colombiana*.

HUANGHOCERAS BRYANI, NEW NAME

JOHN A. YOUNG, JR.
Sun Oil Company, McAllen, Texas

With considerable embarassment I call attention to my mistake of assigning the name *Huanghoceras percostatum* Young (1942, Jour. Paleontology, vol. 16, no. 1, p. 123) to a species from New Mexico after pointing out in the discussion of the genus that *Metacoceras percostatum* Bisat had been assigned to *Huanghoceras* by Yin. It is proposed that the invalid *H. percostatum* Young be replaced by *H. bryani*, which is named in honor of Prof. Kirk Bryan of Harvard University, who initiated me in my studies of the Pennsylvanian of New Mexico.

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REVIEWS

A SOURCE-BOOK OF BIOLOGICAL NAMES AND TERMS, by Edmund C. Jaeger, 256 pp., Charles C Thomas, Springfield, Ill., 1944. $3.50.

To arouse the interest and assist the memory of the biological student untrained in Greek and Latin there have appeared in recent years a number of books in the nature of small dictionaries and lexicons giving lists and definitions of Greek and Latin roots used in the formation of scientific terms. The present source-book contains a nearly complete catalog of such radicals, omitting chiefly only those of irregular, recondite, and anagrammatic origin. Most of the listed roots have been used in the formation of generic names, one or more of which are cited in each instance as examples. The biology student will accordingly here find a clue to the meaning of practically any generic name he may wish to analyze. Only those who have tried to compile such lists and find satisfactory examples can fully appreciate the extensive and painstaking work that was necessary in examining the various catalogs of plant and animal names and verifying the etymologies of these terms. The author of this book, therefore, deserves unstinted credit for his thorough and accurate job in preparing what might be called the analytical phase of a word-book.

The scientist interested in the synthetic phase of technical nomenclature to the extent of seeking given roots for the coinage of new terms, will, however, find this book somewhat disappointing in that it lacks an English-Classical finding list. Thus, for example, if he desires to coin a word containing the idea of white, unless he knows that *albus* is the Latin and *leucos* the Greek for white, to say nothing of numerous synonymous radicals, he will be without recourse except to consult other dictionaries having such lists. Nevertheless, this book gives an interesting and helpful discussion in the introductory pages on "How words are built," "Kinds of generic names," "Application of names," and "Transliteration." Line cuts of plants and animals illustrate many examples.

ROLAND W. BROWN

Geological Survey,
U. S. Dept. of the Interior,
Washington 25, D. C.

THE NATURALIST'S LEXICON, by Robert S. Woods, xvii–282 pp., 8 vo. Abbey Garden Press, Pasadena, 1944. $2.75.

This useful lexicon includes some 15,000 classic Latin and latinized Greek words and combining forms used or usable in biological nomenclature, of both plants and animals. It does not list personal and place names, nor words misspelled or wrongly constructed.

The main part of the work comprises a Classical-English lexicon in which all the words defined are in Latin form with the original Greek in parentheses. The lexicon is preceded by a short introduction in which some of the rules of Latin and Greek grammar are set forth. It is followed by a classified English-Classical supplement in which the Latin equivalent of some English words is given. This supplement might profitably have been made longer, for many naturalists are more concerned with coining new names than in learning the meaning of old ones.

The book is well printed in large, clear type. It should prove a useful addition to the reference shelf.

C. WYTHE COOKE

JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 3, PP. 321–331, MAY 1945

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*BASSLER, RAY S., U. S. National Museum, Washington 25, D. C.
BECK, GEORGE F., Central Washington College, Ellensburg, Wash.
BECKER, LT. LEROY, 537 Lincoln St., Princeton, Ill.
BELL, LT. W. CHARLES, Dept. of Geology, Univ. of Texas, Austin 12, Tex.
BENTSON, HERDIS, Standard Oil Co. of Calif., 225 Bush St., San Francisco 20, Calif.
BERGQUIST, HARLAN RICHARD, U. S. Geological Survey, Washington 25, D. C.
BISSELL, HAROLD J., 409 West First St., South, Cedar City, Utah.
BLICK, JOHN C., 3587 Griffith Pk. Blvd., Los Angeles, Calif.
BOCK, WILHELM, North Wales, Pa.
BORGER, HARVEY, D., Creole Petroleum Corp., Jusefin-Maturin, Venezuela, S.A.
BORN, KENDALL E., Tennessee Division of Geology, G-5, State Office Bldg., Nashville 3, Tenn.
BOTERO-RESTREPO, Gilberto, Apt. Aereo 4498, Bogota, Colombia, S.A.
BRADY, LIONEL FRANCIS, 922½ Forest Ave., Tempe, Ariz.
BRAMKAMP, RICHARD ALLAN, c/o CASOC, Bahrein Island, Persian Gulf.
*BRANSON, CARL C., Box 37, Jackson, Ala.
*BRANSON, E. B., 101 Swallow Hall, Univ. of Missouri, Columbia, Mo.
BRANSON, MRS. HERBERTA L. VAN PELT, c/o Prof. D. M. Young, Dept. Geology, Univ. of Kentucky, Lexington, Ky.
BRAUNSTEIN, JULES, Box 1817, Jackson, Miss.
*BRIDGE, JOSIAH, 337 U. S. National Museum, Washington 25, D. C.
BRILL, KENNETH GRAY, JR., 1215 Highland Parkway, St. Paul 5, Minn.
BRÖNNIMANN, PAUL, Institut of Geology, Bernoullianum, Basle, Switzerland.
*BROWN, BARNUM, American Museum of Natural History, New York 24, N. Y.
*BROWN, ROLAND W., 332 U. S. National Museum, Washington 25, D. C.
BROWN, RICHARD ARTHUR, Geological Survey, Dept. Mines and Resources, Ottawa, Ont., Canada.
BROWN, V. ELHOLM, Walker Museum, Taylor Univ., Upland, Ind.
*BUCHER, WALTER H., Dept. of Geology, Columbia Univ., New York 27, N. Y.
BUMP, JAMES DYE, South Dakota School of Mines, Rapid City, S. D.
BUNTON, PAUL B., Spencer Lens Co., Box 4208, Atlanta, Ga.
BURGESS, ANNE EDITH, 116 Livingston St., New Brunswick, N. J.
*BURLING, LANCASTER D., Dept. of Geology, Univ. of Missouri, Columbia, Mo.
BUSH, FREDERIC A., Box 521, Tulsa 2, Okla.
*BUTTS, CHARLES, U. S. National Museum, Washington 25, D. C.

*CAMP, CHARLES L., Museum of Paleontology, Univ. of California, Berkeley 4, Calif.
CAMPBELL, ARTHUR SCHACKLETON, 3011 Regent St., Berkeley 5, Calif.
*CARMAN, J. E., Dept. of Geology, Ohio State Univ., Columbus, Ohio.
CARRIER, JOHN BALDWIN, 510 Petroleum Bldg., Wichita, Kan.
CARTER, ALICK LAYNG, 172 Parkwood Ave., Kenmore 17, New York.
*CASE, ERMINE C., Univ. Museum, Univ. of Michigan, Ann Arbor, Mich.
*CASTER, KENNETH E., Univ. of Cincinnati, Cincinnati 21, Ohio.
*CHANEY, RALPH W., Dept. of Paleontology, Univ. of California, Berkeley 4, Calif.
CHAPPARS, MICHAEL S., Walker Museum, Univ. of Chicago, Chicago 37, Ill.
*CLARK, ALEXANDER, Box 691, Ventura, Calif.
*CLARK, BRUCE L., Dept. of Paleontology, Univ. of California, Berkeley 4, Calif.

CLARK, LT. JOHN, Carnegie Museum, Pittsburgh, Pa.
*CLARK, THOMAS H., Redpath Museum, McGill Univ., Montreal, P.Q., Canada.
*CLEAVES, ARTHUR BAILEY, 21 Cottage St., South Orange, N. J.
*CLEMENTS, F. E., 190 Miradero Lane, Santa Barbara, Calif.
CLIFT, LT. WILLIAM ORRRIN, NRTS, St. Simons Id. Ga.
*CLINE LEWIS MANNING, Geol. Dept., Standard Oil Co. of Texas, Box 1249, Houston 1, Tex.
CLOUD, PRESTON E., JR., 337 U. S. National Museum, Washington 25, D. C.
*COLBERT, EDWIN H., American Museum of Natural History, New York 24, N. Y.
*COLE, W. S., Orton Hall, Ohio State Univ., Columbus, Ohio.
COLLINS, R. LEE, Dept. of Geology, Univ. of Tennessee, Knoxville, Tenn.
*CONDRA, G. E., Univ. of Nebraska, Lincoln 8, Neb.
*COOKE, C. WYTHE, U. S. National Museum, Washington 25, D. C.
COOLEY, MARY ELIZABETH, 703 Forest Ave., Ann Arbor, Mich.
COOPER, BYRON NELSON, Virginia Geological Survey, Box 1428, University, Va.
*COOPER, CHALMER L., Illinois Geological Survey, Urbana, Ill.
*COOPER, G. ARTHUR, U. S. National Museum, Washington 25, D. C.
CORDELL, ROBERT JAMES, 79 Greendale Drive, St. Louis, Mo.
*CORYELL, HORACE N., Dept. of Geology, Columbia Univ., New York 27, N. Y.
CRAIG, LAWRENCE CAREY, U. S. Geological Survey, Washington 25, D. C.
*CRAM, IRA H., 35 E. Wacker Drive, Chicago, Ill.
*CRONEIS, CAREY G., Beloit College, Beloit, Wis.
CROSS, AUREAL T., Dept. of Biology, Univ. of Notre Dame, Notre Dame, Ind.
CULBERTSON, JOHN ARCHER, Continental Oil Co., 610 Oil & Gas Bldg., Houston 1, Tex.
CULLISON, JAMES, Missouri School of Mines, Rolla, Mo.
*CUMINGS, EDGAR R., 358 Bank St., Painesville, Ohio.
*CUSHMAN, JOSEPH A., 76 Brook Road, Sharon, Mass.

*DECKER, CHARLES E., Faculty Exchange, Univ. of Oklahoma, Norman, Okla.
*DEISS, C. F., Dept. of Geology, Montana State Univ., Missoula, Mont.
DENSON, NORMAN MACLAREN, Box 2013, University, Ala.
DORREEN, J. M., N. Z. Petroleum Co., Box 295, Gisborne, New Zealand.
*DORF, ERLING, Dept. of Geology, Princeton Univ., Princeton, N. J.
DRIVER, HERSCHEL L., 630 West Palm Drive, Glendale 2, Calif.
DU BOIS, ERNEST PAUL, Illinois Geological Survey, Urbana, Ill.
DUCKWORTH, ALBERT STONE, 915 College Hill, Cape Girardeau, Mo.
DUDLEY, RUTH MARY, Shell Oil Co., Box 1191, Tulsa 2, Okla.
*DUNBAR, CARL O., Peabody Museum, Yale Univ., New Haven, Conn.
DUNCAN, DONALD CAVE, U. S. Geological Survey, Washington 25, D. C.
DUNCAN, HELEN, U. S. Geological Survey, Washington 25, D. C.
DUNN, LT. PAUL H., USNR, Apt. 12, Carolina Inn, Chapel Hill, N. C.
DURHAM, J. WYATT, Tropical Oil Co., Bogotá, Colombia, S. A.

EASTON, WM. HEYDEN, 3400 Newark St., N.W., Washington 16, D. C.
EFFINGER, WILLIAM LLOYD, 1818 Canal Bldg., New Orleans 12, La.
*EHLERS, GEORGE M., Univ. of Michigan, Ann Arbor, Mich.
*ELIAS, M. K., c/o Conservation & Survey Division, Univ. Nebraska, Lincoln 8, Nebr.
ELLER, E. R., Carnegie Museum, Pittsburgh, Pa.
ELLIS, BROOKS FLEMING, 72 Clarendon Road, Scarsdale, N. Y.
ELLISON, SAMUEL P., JR., Stanolind Oil & Gas Co., Box 1540, Midland, Tex.
*ELLISOR, ALVA C., Humble Oil & Refining Co., Drawer D, Houston, Tex.
EMIELITY, JOSEPH GEORGE, Milwaukee Public Museum, Milwaukee, Wis.
ENDO, RIUJI, The Central National Museum of Manchoukuo, Hsinking, Manchuokuo.
EVITT, WILLIAM R., II, Severna Park, Md.

FALKENBACH, CHARLES H., Frick Laboratories, American Mus. Natural History, New York 24, N. Y.
FANSHAWE, JOHN R., General Petroleum Corp. of California, 424 Securities Bldg., Billings, Mont.
FAUL, HENRY, Union Mines Dev. Corp., 50 E. 42nd St., New York 17, N. Y.
FIENNING, ROBERT L., Pure Oil Co., Inc., Box 271, Tulsa 2, Okla.
FISCHER, ALFRED GEORGE, Stanolind Oil & Gas Co., Box 1118, Tallahassee, Fla.
*FLOWER, ROUSSEAU H., New York State Museum, Albany 1, N. Y.
*FOHS, F. JULIUS, Fohs Oil Co., 1340 Mellie Esperson Bldg., Houston 2, Tex.
FOX, LT. STEVEN KNOWLTON, JR., USNR, Dept. of Geology, Princeton Univ., Princeton, N. J.
FREEMAN, MRS. LOUISE BARTON, Box 680, Lexington, Ky.
*FRICK, CHILDS, American Museum of Natural History, New York 24, N. Y.
*FRITZ, MADELEINE ALBERTA, 388 Brunswick Ave., Toronto 4, Ont., Canada.
FRIZZELL, DON L., Dept. of Geology, Univ. of Texas, Austin 12, Tex.
FRY, WILLIAM WILLCOX, 6420 Cecil Ave., St. Louis, Mo.
*FURLONG, EUSTACE L., California Inst. of Technology, Pasadena 4, Calif.
FURNISH, WILLIAM M., Rt. 1, Tyler, Tex.

GALE, HOYT RODNEY, 669 Sturtevant Drive, Sierra Madre, Calif.
*GALLOWAY, J. J., Indiana Univ., Bloomington, Ind.
*GARDNER, JULIA A., U. S. Geological Survey, Washington 25, D. C.
GARRETT, MRS. EUNICE PETERSON, 336 N. Princeton Ave., Swarthmore, Pa.
*GAZIN, MAJ. CHARLES LEWIS, 1629 Columbia Rd., Washington 9, D. C.
GILBOE, JOHN DANIEL, Box 999, Bakersfield, Calif.
GILDERSLEEVE, BENJAMIN, 209 E. Woodrow Ave., Knoxville 18, Tenn.
*GILMORE, C. W., U. S. National Museum, Washington 25, D. C.
*GOLDRING, WINIFRED, New York State Museum, Albany 1, N. Y.
*GORDON, CLARENCE E., Massachusetts State College, Amherst, Mass.
GORDON, MACKENZIE, JR., 1290 Hamilton Ave., Palo Alto, Calif.
GRAHAM, JOSEPH J., Dept. of Paleontology, Univ. of California, Berkeley 4, Calif.
*GRANT, U. S., IV, Univ. of California at Los Angeles, Los Angeles 24, Calif.
GREACEN, KATHERINE FIELDING, Hunt Oil Co., Midland, Tex.
*GREENE, F. C., Biltmore Arms Apt., 900 E. 9th St., Kansas City 6, Mo.
GREGORY, JOSEPH TRACY, Univ. of Michigan, Ann Arbor, Mich.
*GREGORY, W. K., American Museum of Natural History, New York 24, N. Y.
GRIES, JOHN PAUL, Magnolia Petroleum Co., Box 633, Midland, Tex.
GRILEY, H. L., Sun Oil Co., 1608 Walnut St., Philadelphia, Pa.
GROSSMAN, WILLIAM LEWIS, c/o Mrs. W. L. Grossman, Andover, N. Y.
GROVE, BRANDON H., 3820–39th St., N.W., Washington 16, D. C.
GUTSCHICK, RAYMOND C., Magnolia Petroleum Co., Box 1828, Oklahoma City 1, Okla.

*HAAS, OTTO H., American Museum of Natural History, New York 24, N. Y.
HADLEY, WADE HAMPTON, JR., Pure Oil Co., Room 747, Canal Bldg., New Orleans 12, La.
HAGAN, WALLACE W., 520 S. 7th St., Chickasha, Okla.
*HANNA, G. DALLAS, California Acad. of Sciences, San Francisco 18, Calif.
*HANNA, M. A., Gulf Oil Corp., Box 2100, Houston, Tex.
HARBISON, ANNE, The Barclay, Rittenhouse Square, Philadelphia, Pa.
HARLTON, BRUCE H., The Amerada Petroleum Corp., Drawer 2040, Tulsa, Okla.
*HARRIS, GILBERT D., 126 Kelvin Place, Ithaca, N. Y.
HARRIS, REGINALD W., Phillips Petroleum Co., Midland, Tex.
*HARTNAGEL, CHRIS A., Slingerlands, Albany Co., N. Y.
HASS, WILBERT H., 333 U. S. National Museum, Washington 25, D. C.
*HAYNES, WINTHROP P., Room 2150, 30 Rockefeller Plaza, New York 20, N. Y.

HAZZARD, JOHN C., 1119 Union Oil Bldg., 617 W. 7th St., Los Angeles 14, Calif.
*HEDBERG, HOLLIS D., Mene Grande Oil Co., Apartado 45, Barcelona, Venezuela, S. A.
HEMINWAY, CAROLINE ELLA, Shell Oil Co., Inc., 641 M. and M. Bldg., Houston 2, Texas.
*HENBEST, LLOYD G., 327 U. S. National Museum, Washington 25, D. C.
HERPICH, FRED C., 491 Ridge Road, Hamden 14, Conn.
HIBBARD, CLAUDE W., Kansas Univ., Museum of Vertebrate Paleontology, Lawrence, Kan.
HIBBARD, RAYMOND R., 219 Bissell Ave., Buffalo 11, N. Y.
HINCHEY, NORMAN SHREVE, Dept. of Geology, Washington Univ., St. Louis 5, Mo.
*HOFFMEISTER, J. E., Dept. of Geology, Univ. of Rochester, Rochester, N. Y.
HOLLINGSWORTH, RICHARD V., Lab. of Paleontology, Box 51, Midland, Tex.
HOLZWASSER, FLORRIE, Barnard College, Columbia Univ., New York 27, N. Y.
HOPF, ROBERT W., 700 Monroe Ave., Elizabeth 4, N. J.
HOSKINS, JOHN HOBART, Dept. of Botany, Univ. of Cincinnati, Cincinnati 21, Ohio.
*HOWE, H. V., School of Geology, Louisiana State Univ., Baton Rouge 3, La.
*HOWELL, B. F., Dept. of Geology, Princeton Univ., Princeton, N. J.
*HUBBARD, BELA, Standard Oil Co. of N. J., 30 Rockefeller Plaza, New York 20, N. Y.
HUDDLE, J. W., Dept. of Geology, Univ. North Carolina, Chapel Hill, N. C.
HUFFMAN, GEORGE GARRETT, 1334 Daytona Drive, Corpus Christi, Tex.
HUMPHREY, WILLIAM E., Texas Petroleum Co., Apt. 267, Caracas, Venezuela, S. A.
*HUSSAKOF, LOUIS, 1537 50th St., Brooklyn 19, N. Y.
HUSSEY, RUSSELL C., 595 Riverview Drive, Rt. 5, Ann Arbor, Mich.
HUTCHINS, FORBES MEREDITH, 3524 Ontario Ave., Montreal, P. Q., Canada.
HUTTO, MRS. MASON P., c/o Dr. C. E. Brown, 3231 Washington Blvd., Chicago, Ill.

*IMLAY, RALPH W., 331 U. S. National Museum, Washington 25, D. C.
*ISRAELSKY, MERLE CATHCART, Union Producing Co., 841 M. & M. Bldg., Houston 2, Tex.

*JACKSON, ROBERT T., Peterborough, N. H.
JEFFORDS, RUSSELL M., P. O. Box 854, Morgantown, W. Va.
JENNINGS, OTTO E., Carnegie Museum, Pittsburgh, Pa.
JENNINGS, PHILIP H., Magnolia Petroleum Co., Box 872, Lake Charles, La.
*JEPSEN, GLENN L., Dept. of Geology, Princeton Univ., Princeton, N. J.
JEWETT, JOHN MARK, State Geological Survey, Lawrence, Kan.
*JOHNSON, J. HARLAN, Box 306, Golden, Colo.
JOHNSTON, FRANCIS NEWLANDS, 4 East Leland St., Chevy Chase 15, Md.

*KAY, MARSHALL, Dept. of Geology, Columbia Univ., New York 27, N. Y.
KEEN, A. MYRA, Box 1563, Stanford University, Calif.
KEENAN, JAMES E., Bay Petroleum Corp., Box 957, Denver, Colo.
*KELLOGG, REMINGTON, U. S. National Museum, Washington 25, D. C.
*KELLUM, LEWIS B., Museum of Paleontology, Univ. of Michigan, Ann Arbor, Mich.
KELLY, WILLIAM A., Michigan State College, East Lansing, Mich.
KENNEDY, I. A., 220 3rd Ave. E., Kalispell, Mont.
KENT, MRS. LOIS SCHOONOVER, U. S. Geological Survey, Washington 25, D. C.
*KEW, W. S. W., Standard Oil Co. of Calif., 1100 Union St., San Francisco 9, Calif.
KINDLE, CECIL H., 590 Riverside Drive, New York 31, N. Y.
*KING, ROBERT E., 613 N. Lake St., Carlsbad, N. M.
*KIRK, EDWIN, U. S. National Museum, Washington 25, D. C.
*KLEINPELL, ROBERT M., 1278 Mar Vista Ave., Pasadena 6, Calif.
*KNIGHT, JAMES BROOKES, Dept. of Geology, Princeton University, Princeton, N. J.
*KNIGHT, S. H., Univ. of Wyoming, Laramie, Wyo.
KNOX, ARTHUR STEWART, 65 Bromfield Road, West Somerville, Mass.
KOERNER, HAROLD E., Dept. of Geology, Lafayette College, Easton, Pa.
KŘÍŽ, STANISLAV E., Standard Oil Bldg., 605 W. Olympia Blvd., Los Angeles 15, Calif.
KUMMEL, BERNHARD, 2400 N. Main St., Racine, Wis.

*LADD, HARRY S., U. S. National Museum, Washington 25, D. C.
LAIRD, WILSON M., Dept. of Geology, Univ. of North Dakota, Grand Forks, N. D.
LALICKER, CECIL GORDON, Faculty Exchange, Univ. of Oklahoma, Norman, Okla.
LAMBORN, MRS. HELEN MORNINGSTAR, 224 Piedmont Road, Columbus, Ohio.
LAMOTTE, LT. COL. ROBERT S., 667 Aileen St., Oakland, Calif.
LANDES, ROBERT W., International Petroleum Co., Casilla 206, Guayaquil, Ecuador, S. A.
*LAUDON, LOWELL R., Univ. of Kansas, Lawrence, Kan.
*LAVERDIÈRE, JOSEPH W., Faculté des Sciences, Boulevard de l'Entente, Quebec, Canada.
LEITH, EDWARD I., Dept. of Geology. Univ. of Manitoba, Winnipeg, Man., Canada.
LEONARD, ARTHUR BYRON, 205 Snow Hall, University of Kansas, Lawrence, Kan.
*LOCHMAN, CHRISTINA, Dept. of Geology, Mount Holyoke College, South Hadley, Mass.
LOEBLICH, ALFRED R., JR., 452 College Ave., Norman, Okla.
LOEBLICH, HELEN TAPPAN, 452 College Ave., Norman, Okla.
LOWENSTAM, HEINZ A., Illinois Geological Survey, 205 Natural Resources Bldg., Urbana, Ill.
LOZO, FRANK EDGAR, JR., Shell Oil Co., Inc., 641 M. and M. Bldg., Houston 2, Tex.
*LULL, RICHARD S., Peabody Museum, Yale Univ., New Haven, Conn.
*LUPHER, RALPH L., Dept. of Geology, State College of Washington, Pullman, Wash.

MACALPIN, ARCHIE J., Box 177, Univ. of New Mexico, Albuquerque, N. M.
*MACGINTIE, LT. HARRY, 212 So. Yale St., Albuquerque, N. M.
MACNEIL, F. STEARNS, U. S. National Museum, Washington 25, D. C.
MARTIN, LOIS T., 2218 D St., Bakersfield, Calif.
*MATHER, K. F., Harvard Geological Museum, Cambridge 38, Mass.
MAXSON, LT. COL. JOHN HAVILAND, Dept. of Geology, Calif. Inst. of Technology, Pasadena 4, Calif.
*MCFARLAN, ARTHUR C., 1712 Fairway Drive, Lexington, Ky.
MCGLAMERY, WINIFRED, State Geological Survey, University, Ala.
MCGREGOR, J. H., Dept. of Zoology, Columbia Univ., New York 27, N. Y.
*MCKEE, EDWIN DINWIDDIE, Dept. of Geology, Univ. of Arizona, Tucson, Ariz.
*MCNAIR, ANDREW HAMILTON, Lewiston, Vt.
*MEHL, MAURICE G., Dept. of Geology, Univ. of Missouri, Columbia, Mo.
MELLEN, F. F., Leavell Woods, Jackson, Miss.
MENCHER, ELY, Socony Vacuum Oil Co., Apt. 246, Caracas, Venezuela, S. A.
*MERRIAM, CHARLES W., U. S. Geological Survey, Pioche, Nev.
*MERRIAM, JOHN C., Dept. Geological Sciences, Calif. Inst. Technology, Pasadena 4, Calif.
MESSINA, ANGELINA ROSE, American Museum of Natural History, New York 24, N. Y.
*MEYERHOFF, HOWARD A., Dept. of Geology, Smith College, Northampton, Mass.
*MILLER, ARTHUR K., Dept. of Geology, State Univ., Iowa City, Iowa.
*MILLER, RALPH LEROY, U. S. Geological Survey, Washington 25, D. C.
MOORE, CARL A., Box 1151, Seminole, Okla.
MOORE, PRENTISS D., Box 753, Midland, Tex.
*MOORE, MAJ. RAYMOND C., Univ. of Kansas, Lawrence, Kan.
MORAN, ROBERT B., 437 S. Hill St., Los Angeles 13, Calif.
MOREMAN, W. L., 1308 Drexel Blvd., Oklahoma City, Okla.
*MORSE, WILLIAM C., Univ. of Mississippi, University, Miss.
*MULLER, SIEMON W., Dept. of Geology, Stanford University, Calif.

NADEAU, MRS. E. H., 1018 Bomparte Ave., Webster Groves 19, Mo.
NEELY, JOSEPH, Lovell, Wyo.
NELSON, ELMER, R., JR., Public Museum, Milwaukee 3, Wis.
*NEWELL, NORMAN D., Dept. of Geology, Johns Hopkins Univ., Baltimore, Md.
*NORTHROP, STUART A., Dept. of Geology, Univ. of New Mexico, Albuquerque, N. M.

O'GARA, WILLIAM THOMAS, 2231 Hurley Ave., Fort Worth, Tex.
*OKULITCH, VLADIMIR J., Dept. of Geology, Univ. of British Columbia, Vancouver, B. C., Canada.
*OLSSON, AXEL A., 48 Woodside Ave., Gloversville, N. Y.
OVERMAN, C. I., Birch Tree, Mo.

*PACK, R. W., P. O. Box 2831, Beaumont, Tex.
*PACKARD, EARL L., 13 Edgewood Way, Corvallis, Ore.
*PALMER, MRS. D. K., Neptuno 1060, Havana, Cuba.
*PALMER, MRS. KATHERINE VAN WINKLE, 206 Oakhill Road, Ithaca, N. Y.
PEABODY, FRANK E., Museum of Paleontology, Univ. of California, Berkeley 4, Calif.
*PECK, CAPT. RAYMOND E., 501 W. Agarita, San Antonio 1, Tex.
*PECK, W. H., Box 212, Ekalaka, Mont.
*PETRUNKEVITCH, ALEXANDER, Osborn Zool. Laboratory, Yale Station, New Haven, Conn.
*PHLEGER, FRED B., JR., Dept. of Geology, Amherst College, Amherst, Mass.
PLOGER, LOUIS WILLIAM, Dept. of Geology, Syracuse Univ., Syracuse, N. Y.
*PLUMMER, FREDERICK B., Bureau of Economic Geology, Univ. of Texas, Austin, Tex.
*PLUMMER, MRS. HELEN, 3109 Walling Drive, Austin, Tex.
*POHL, ERWIN R., Horse Cave, Ky.
POPENOE, WILLIS PARKISON, Calif. Inst. of Technology, Pasadena 4, Calif.
POTTER, LT. FRANKLIN CARL, 1417 Oak Ave., Evanston, Ill.
PRICE, JOHN WILLIAM, Franklin & Marshall College Museum, Lancaster, Pa.
PROUTY, CHILTON EATON, U. S. Geological Survey, Box 175, Centerville, Tenn.

QUIGLEY, PVT. CLAUDE MERLE, JR., 37235922, Co. B, 30th Engineers, Topo. Bn., A.P.O. 512, c/o Postmaster, New York, N. Y.

RAINWATER, MRS. E. H., 1305 Mitchell Ave., Tallahassee, Fla.
*RAYMOND, PERCY E., Museum of Comparative Zoology, Cambridge, 38 Mass.
READ, WILLIAM F., 28 Stephenson Hall, Lawrence College, Appleton, Wis.
*REEDS, CHESTER A., P. O. Box 142, Ghent, N. Y.
*REESIDE, JOHN B., JR., P. O. Box 177, Hyattsville, Md.
REIMANN, IRVING G., Buffalo Museum of Science, Buffalo, N. Y.
*REINHART, PHILIP WINGATE, 505 Park Ave., Casper, Wyo.
RENFRO, MILLICENT, 2901 Bomar Ave., Ft. Worth 3, Tex.
RICHARDS, EDWARD F., Dept. of Geology, Univ. of Alabama, University, Ala.
*RICHARDS, HORACE GARDINER, Acad. of Natural Sciences, Philadelphia 3, Pa.
RICHARDSON, EUGENE S., Dept. of Geology, Bryn Mawr College, Bryn Mawr, Pa.
RICHEY, CPL. KING A., 38122294, 33rd Photo Rcn. Sq., A.P.O. 151, c/o Postmaster, New York, N. Y.
RIGNEY, CHAPLAIN (CAPT.) HAROLD WILLIAM, 1260 AAF Base Unit, NAFD-ATC, A.P.O. 396, c/o Postmaster, New York, N. Y.
*ROBERTS, JOSEPH K., Box 1471, University Station, Charlottesville, Va.
ROBINSON, WILBUR I., Texas Technological College, Lubbock, Tex.
*ROMER, A. S., Museum of Comparative Zoology, Cambridge 38, Mass.
ROOT, TOWNER B., P. O. Box 218, Hamilton. N. Y.
ROTHWELL, W. THOMAS, JR., Richfield Paleontology Lab., P. O. Box 470, Long Beach 1, Calif.
*RUEDEMANN, RUDOLF, New York State Museum, Albany 1, N. Y.
*RUSSELL, LORIS S., Royal Ontario Museum of Palaeontology, Bloor St. & Avenue Rd., Toronto 5, Ont., Canada.
RUTH, JOHN W., 529 Las Tunas Drive, Arcadia, Calif.
RYNIKER, CHARLES, Gulf Oil Corp., Gypsy Division, Box 661, Tulsa 2, Okla.

SALMON, ELEANOR SEELY, 521 West 112th St., New York 25, N. Y.
SANDER, CAPT. NESTOR J., O 337770, Censorship Br., INC, A.P.O. 512, c/o Postmaster, New York, N. Y.
*SANDIDGE, JOHN R., Magnolia Petroleum Co., 1704 Alamo Natl. Bldg., San Antonio, Tex.
SANFORD, JOHN THERON, Magnolia Petroleum Co., Box 1828, Oklahoma City 1, Okla.
*SCHENCK, MAJ. HUBERT G., Box 1528, Stanford Univ., Calif.
SCHENK, EDWARD THEODORE, 537 Avenue I, Boulder City, Nev.
SCHEVILL, WILLIAM E., Museum of Comparative Zoology, Cambridge 38, Mass.
*SCHLAIKJER, ERICH M., Brooklyn College, Bedford Avenue & Avenue H., Brooklyn, N. Y.
*SCHOPF, JAMES M., Bureau of Mines, 4800 Forbes St., Pittsburgh 13, Pa.
*SCOTT, GAYLE, Dept. of Geology, Texas Christian Univ., Fort Worth, Tex.
*SCOTT, HAROLD WILLIAM, 246 Nat. History Bldg., Univ. of Illinois, Urbana, Ill.
*SCOTT, WILLIAM BERRYMAN, Guyot Hall, Princeton Univ., Princeton, N. J.
SECRIST, MARK H., Dept. of Geology, Johns Hopkins Univ., Baltimore, Md.
*SELLARDS, ELIAS H., Bureau of Economic Geology, Univ. of Texas, Austin 12, Tex.
SHIDELER, WILLIAM H., 110 S. Campus Ave., Oxford, Ohio.
*SHIMER, HERVEY W., Massachusetts Inst. of Technology, Cambridge 38, Mass.
*SHROCK, ROBERT R., Dept. of Geology, Mass. Inst. of Technology, Cambridge 38, Mass.
*SIMPSON, GEORGE G., American Museum of Natural History, New York 24, N. Y.
SINCLAIR, GEORGE WINSTON, Sir George Williams College, Montreal, P. Q., Canada.
*SKINNER, MORRIS F., Frick Laboratories, American Mus. Natural History, New York, 24, N. Y.
SLOSS, LAURENCE L., Montana School of Mines, Butte, Mont.
*SMITH, BURNETT, West Lake St., Skaneateles, N. Y.
*SMITH, EDWARD S. C., Dept. of Geology, Union College, Schenectady 8, N. Y.
SMITH, ERNEST RICE, 309 Greenwood Ave., Greencastle, Ind.
SMITH, HOMER JAMES, Socony-Vacuum Oil Co. of Colombia, Bogotá, Colombia, S. A.
*SMITH, STANLEY, The University, Bristol, England.
SOUTHWORTH, CHARLES H., Box 151, Thedford, Ontario, Canada.
*SPIEKER, EDMUND M., Ohio State Univ., Columbus, Ohio.
SPIVEY, ROBERT CHARLES, Shell Oil Co., Inc., Midland, Tex.
STAINBROOK, MERRILL A., Dept. of Geology, Texas Technological College, Lubbock, Tex.
*STANTON, T. W., 54 S St., N.W., Washington 1, D. C.
*STAUFFER, CLINTON R., 153 S. Hermosa Ave., Sierra Madre, Calif.
*STEPHENSON, L. W., 331 U. S. National Museum, Washington 25, D. C.
STEPHENSON, MORTON B., Stanolind Oil & Gas Co., Box 3092, Houston, Tex.
STERNBERG, CHARLES WILLIAM, Atlantic Refining Co., 431 Wyoming Natl. Bank Bldg., Casper, Wyo.
*STETSON, HENRY C., Museum of Comparative Zoology, Cambridge 38, Mass.
*STEWART, GRACE A., Dept. of Geology, Ohio State Univ., Columbus, Ohio.
STEWART, RALPH B., 405 U. S. National Museum, Washington 25, D. C.
STIRTON, R. A., Dept. of Paleontology, Univ. of California, Berkeley 4, Calif.
*STOCK, CHESTER, California Inst. of Technology, Pasadena 4, Calif.
*STOCKDALE, PARIS B., Univ. of Tennessee, Knoxville, Tenn.
STONER, REGINALD C., Standard Oil Building, San Francisco 20, Calif.
STOUT, THOMPSON M., Frick Lab., American Mus. Natural History, New York 24, N. Y.
*STOVALL, JOHN WILLIS, Univ. of Oklahoma, Norman, Okla.
*STOYANOW, ALEXANDER, Univ. of Arizona, Tucson, Ariz.
STUBBS, SIDNEY ALTON, P. O. Box 132, Bradenton, Fla.
STUCKEY, CHARLES WAINWRIGHT, JR., Stanolind Oil & Gas Co., Box 3092, Houston 1, Texas.
STUMM, ERWIN CHARLES, Dept. of Geology, Oberlin College, Oberlin, Ohio.
STURGEON, MYRON THOMAS, Michigan State Normal College, Ypsilanti, Mich.
SUMMERSON, CHARLES H., Box 177, Univ. of New Mexico, Albuquerque, N. Mex.

*SUTTON, A. H., Aluminum Ore Company, Rosiclare, Ill.
SWANN, DAVID HENRY, State Geological Survey, Urbana, Ill.
*SWARTZ, CHARLES K., Johns Hopkins Univ., Baltimore, Md.
*SWARTZ, FRANK M., 722 N. Atherton St., State College, Pa.

*TALBOT, MIGNON, Morgan St., South Hadley, Mass.
TAYLOR, EDWARD HARRISON, 118 Snow Hall, Univ. of Kansas, Lawrence, Kan.
*TEICHERT, CURT, Univ. of Western Australia, Crawley, Western Australia.
*THALMANN, HANS E., P. O. Box 803, Guayaquil, Ecuador, S. A.
THOMAS, HORACE D., Univ. of Wyoming, Laramie, Wyo.
*THOMAS, NORMAN LOUIS, P. O. Box 38, Bakersfield, Calif.
*THOMPSON, MARCUS LUTHER, Univ. of Kansas, Lawrence, Kan.
TODD, MARGARET RUTH, 76 Brook Road, Sharon, Mass.
TOEPELMANN, WALTER C., Univ. of Colorado, Boulder, Colo.
*TOLMACHOFF, I. P., Carnegie Museum, Pittsburgh, Pa.
TOULMIN, LYMAN D., JR., Geological Survey of Alabama, University, Ala.
TROMP, S. W., c/o Netherlands Consulate, Brisbane, Queensland, Australia.
*TURNER, F. E., Texas Agricultural and Mechanical College, College Station, Tex.
*TWENHOFEL, WILLIAM H., Univ. of Wisconsin, Madison, Wis.

UNKLESBAY, ATHEL G., U. S. Geol. Survey, P. O. Drawer 631, Tallahassee, Fla.

VAN HOUTEN, LT. (j.g.) F. B., USNR, Navy 913 B 4A, c/o Fleet P.O., New York, N. Y.
*VAN TUYL, FRANCIS M., Colorado School of Mines, Golden, Colo.
*VAUGHAN, T. WAYLAND, 3333 P St., N.W., Washington 7, D. C.
VESTAL, FRANKLIN E., 519 3rd Ave., South, Columbus, Miss.
*VOKES, HAROLD E., 340 U. S. National Museum, Washington 25, D. C.

WAAGÉ, KARL M., U. S. Geological Survey, Washington 25, D. C.
WALDRAM, ENSIGN ROBERT J., 332 Stafford St., Washington, Mo.
WALKER, MYRL VINCENT, Yosemite National Park, Calif.
*WANLESS, HAROLD R., 126 Natural History Bldg., Univ. of Illinois, Urbana, Ill.
WARD, FRANK HAWLEY, P. O. Box 24, Beechwood Station, Rochester, N. Y.
*WARREN, PERCIVAL S., Univ. of Alberta, Edmonton, Alta., Canada.
*WARTHIN, ALDRED SCOTT, JR., Dept. of Geology, Vassar College, Poughkeepsie, N. Y.
*WEAVER, CHARLES E., Dept. of Geology, Univ. of Washington, Seattle, Wash.
*WELLER, J. MARVIN, State Geological Survey of Illinois, Urbana, Ill.
WELLES, SAMUEL PAUL, Museum of Paleontology, Univ. of California, Berkeley 4, Calif.
WELLS, DANA, Dept. of Geology, W. Va. Univ., Mineral Industries Bldg., Morgantown, W. Va.
*WELLS, JOHN WEST, Dept. of Geology, Ohio State Univ., Columbus, Ohio.
WERNER, COURTNEY, Dept. of Geology, Washington Univ., St. Louis 5, Mo.
*WETMORE, ALEXANDER, U. S. National Museum, Washington 25, D. C.
*WHEELER, LT. HARRY E., USNR, 4741 Homer Ave., S.E., Washington 20, D. C.
WHIPPLE, G. LESLIE, Richmond Expl. Co. of Venezuela, Padre Sierra A. Muñoz 16, Caracas, Venezuela, S. A.
*WHITCOMB, LAWRENCE, Dept. of Geology, Lehigh Univ., Bethlehem, Pa.
WHITE, THEODORE E., Museum of Comparative Zoology, Cambridge 38, Mass.
WHITMORE, FRANK C., JR., Geological Survey, Washington 25, D. C.
*WHITNEY, F. L., Univ. of Texas, Austin, Tex.
*WICKENDEN, ROBERT THOMAS DAUBIGNY, Geological Survey of Canada, Ottawa, Canada.
WILDER, BEVERLY B., 5434 Miles Ave., Oakland 9, Calif.
*WILLARD, BRADFORD, Dept. of Geology, Lehigh Univ., Bethlehem, Pa.
*WILLIAMS, JAMES STEELE, U. S. Geological Survey, Washington 25, D. C.

WILLIAMS, JAMES STEWART, Dept. of Geology, Utah Agricultural College, Logan, Utah.
*WILLIAMS, MERTON Y., Univ. of British Columbia, Vancouver, B. C., Canada.
*WILSON, C. W., JR., Dept. of Geology, Vanderbilt Univ., Nashville, Tenn.
WILSON, LESLIE E., Matthew Library of Paleontology, Univ. of California, Berkeley 4, Calif.
*WILSON, ROBERT WARREN, Dept. of Geology, Univ. of Colorado, Boulder, Colo.
WINKLER, VIRGIL DEAN, Standard Oil Co. of Venezuela, Caripito, Venezuela, S. A.
WINTON, W. M., Texas Christian Univ., Fort Worth, Tex.
*WOOD, MAJ. ALBERT ELMER, c/o Mrs. F. W. Wright, 398 Upper Mountain Ave., Upper Montclair, N. J.
*WOOD, CAPT. HORACE E., II, Post Hq., Craig Field, Selma, Ala.
*WOODRING, WENDELL P., U. S. Geological Survey, Washington 25, D. C.

YOUNG, FREDERICK PENTZ, JR., 430 West 118th St., New York, N. Y.
YOUNG, JOHN A., JR., Box 1270, McAllen, Tex.
YOUNGQUIST, ENSIGN WALTER L., USNR, 5027 Eleventh Ave. S., Minneapolis 7, Minn.

CORRESPONDENTS DECEASED

BATHER, DR. F. A. Died Mar. 20, 1934.
BOULE, MARCELLIN. Died July 19, 1942.
BUCKMAN, S. S. Died Feb. 26, 1929.
CANU, FERDINAND, Died Feb. 12, 1932.
CHAPMAN, FREDERICK. Died Dec. 10, 1943.
COBBOLD, EDGAR STERLING. Died Nov. 20, 1936.
DEPÉRET, PROF. CHARLES. Died May 17, 1939.
KAIER, PROF. JOHAN. Died Oct. 31, 1931.
KOKEN, E. Died Nov. 24, 1912.
KOLIHA, DR. JAN. Died April 7, 1939.
NATHORST, DR. A. C. Died Jan. 20, 1921.
PILGRIM, DR. G. E. Died, Sept. 15, 1943.
POMPECKI, DR. J. F. Died July 8, 1930.
STEFANINI, PROF. G. Died Sept. 15, 1938.
WOODWARD, DR. H. Died Sept. 6, 1921.

MEMBERS AND FELLOWS DECEASED

*ALDRICH, TRUMAN H. Died Apr. 28, 1932.
*AMI, HENRY M. Died Jan. 4, 1931.
ARMSTRONG, EDWIN J. Died Jan. 21, 1925.
BALL, OSCAR M. Died Nov. 11, 1942.
*BARRELL, JOSEPH. Died May 4, 1919.
BARROWS, ALBERT L. Died Nov. 7, 1942.
*BEEDE, JOSHUA W. Died Feb. 27, 1940.
BELANSKI, CHARLES H. Died Apr. 30, 1929.
BENSLEY, B. A. Died Jan. 20, 1934.
BILLINGS, W. R. Died Mar. 1, 1920.
BOSTWICK, THOMAS A. Died Apr. 1923.
*BROWN, T. C. Died Feb. 28, 1934.
*CALVIN, SAMUEL. Died Apr. 17, 1911.
*CLARK, WM. BULLOCK. Died July 27, 1917.
*CLARKE, JOHN M. Died May 29, 1925.
*CLELAND, HERDMAN F. Died Jan. 24, 1935.
*CROOK, A. R. Died May 30, 1930.
CROZEL, GEORGE. Died Oct. 1921.
DALL, W. H. Died Mar. 27, 1927.
*DEAN, BASHFORD. Died Dec. 6, 1928.
*DERBY, ORVILLE A. Died Nov. 27, 1915.
*DICKERSON, ROY E. Died Feb. 24, 1944.
DONEGHY, JOHN T. Died June 29, 1921.
DOUGLASS, EARL. Died Jan. 13, 1931.
*EASTMAN, CHAS. R. Died Sept. 27, 1918.
*EDWARDS, IRA. Died October 31, 1943.
*FOERSTE, AUGUST F. Died Apr. 23, 1936.
*FONTAINE, WM. M. Died Apr. 30, 1913.
GIBB, HUGH. Died Feb. 28, 1932.
*GIDLEY, JAMES WM. Died Sept. 26, 1931.
GILL, THEODORE N. Died Sept. 25, 1914.
*GIRTY, GEORGE HERBERT. Died Jan. 27, 1939.
GORDON, ROBERT H. Died May 10, 1910.
GRAHAM, ROY. Died Aug. 9, 1939.
*GRANGER, WALTER. Died Sept. 7, 1941.
*GURLEY, W. F. E. R. Died June 27, 1943.
HAMLIN, HOMER. Died July, 1920.
HARPER, GEORGE W. Died Aug. 19, 1918.
HAWVER, J. C. Died May 15, 1914.
*HAY, O. P. Died Nov. 2, 1930.
*HENDERSON, JUNIUS. Died. Nov. 4, 1937.
*HOLLAND, WM. J. Died Dec. 15, 1932.
*HOLLICK, ARTHUR. Died Mar. 11, 1933.
HOLMES, WALTER W. Died Nov. 13, 1938.
*HUDSON, GEORGE H. Died Mar. 19, 1934.
*HYDE, JESSE E. Died July 3, 1936.
JOHNSTON, C. STUART. Died July 23, 1939.
KELLY, HOWARD A. Died January 12, 1943.
KEYTE, I. A. Died May 29, 1931.
*KINDLE, EDWARD M. Died Aug. 29, 1940.
*KNOWLTON, FRANK H. Died Nov. 21, 1926.
*LAMBE, L. M. Died Mar. 12, 1919.
*LEE, WILLIS T. Died June 17, 1926.
*LOOMIS, FREDERICK B. Died July 28, 1937.
LUSK, RALPH G. Died July 27, 1927.
LUTHER, D. D. Died Dec. 17, 1923.
LYON, VICTOR W. Died Aug. 17, 1919.
MACBRIDE, THOMAS H. Died Mar. 27, 1934.
*MANSFIELD, WENDELL C. Died July 24, 1939.
MARTIN, BRUCE. Died Dec. 23, 1919.

MARTIN, HANDELL T. Died Jan. 15, 1931.
MATTHEW, GEO. F. Died Apr. 17, 1923.
*MATTHEW, W. D. Died Sept. 24, 1930.
MEACHEM, R. P. Died. Feb. 13, 1934.
MESLER, RECTOR D. Died Feb. 25, 1944.
MOODY, W. L. Died Oct. 9, 1920.
NOBLE, G. KINGSLEY. Died Dec. 9, 1940.
*NOÉ, ADOLF C. Died Apr. 10, 1939.
NOMLAND, JORGEN O. Died May 7, 1943.
*PARKS, WM. A. Died Oct. 3, 1936.
PATTEN, WM. Died Oct. 23, 1932.
*PENHALLOW, DAVID P. Died Oct. 20, 1910.
PETERSON, O. A. Died Nov. 13, 1933.
*PROSSER, C. S. Died Sept. 11, 1916.
*RATHBUN, MARY JANE. Died Apr. 4, 1943.
*RESSER, CHARLES E. Died Sept. 18, 1943.
ROUNDY, PAUL V. Died June 21, 1937.
*SCHUCHERT, CHARLES. Died Nov. 20, 1942.
*SEELY, HENRY M. Died May 4, 1917.
*SINCLAIR, W. J. Died Mar. 25, 1935.
SLOCUM, ARTHUR W. Died Nov. 20, 1937.
*SPRINGER, FRANK. Died Sept. 22, 1927.
TEGLAND, NELLIE M. Died Dec. 1930.
TELLER, EDGAR E. Died July 19, 1923.
*THOMAS, A. O. Died Jan. 13, 1931.
TIEJE, ARTHUR J. Died Jan. 25, 1944.
*TILTON, J. L. Died Nov. 17, 1930.
TWITCHELL, G. B. Died Apr. 28, 1933.
*TWITCHELL, M. W. Died Apr. 8, 1927.
*ULRICH, EDWARD O. Died Feb. 23, 1944.
*VAN INGEN, GILBERT. Died July 7, 1925.
*VODGES, ANTHONY W. Died Feb. 8, 1923.
*WALCOTT, CHARLES D. Died Feb. 9, 1927.
WARING, CHARLES A. Died Nov. 5, 1918.
WARNER, WILLIAM C. Died Sept. 29, 1941.
WEINZIERL, MRS. J. F. Died Sept. 28, 1928.
*WELLER, STUART. Died Aug. 5, 1927.
*WHITE, DAVID. Died Feb. 7, 1935.
*WHITFIELD, R. P. Died Apr. 6, 1910.
*WILLIAMS, HENRY S. Died July 31, 1918.
WILLISTON, S. W. Died Aug. 30, 1918.
WILSON, HERRICK E. Died Jan. 24, 1925.
WHITTAKER, EDW. Died Sept. 14, 1924.

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